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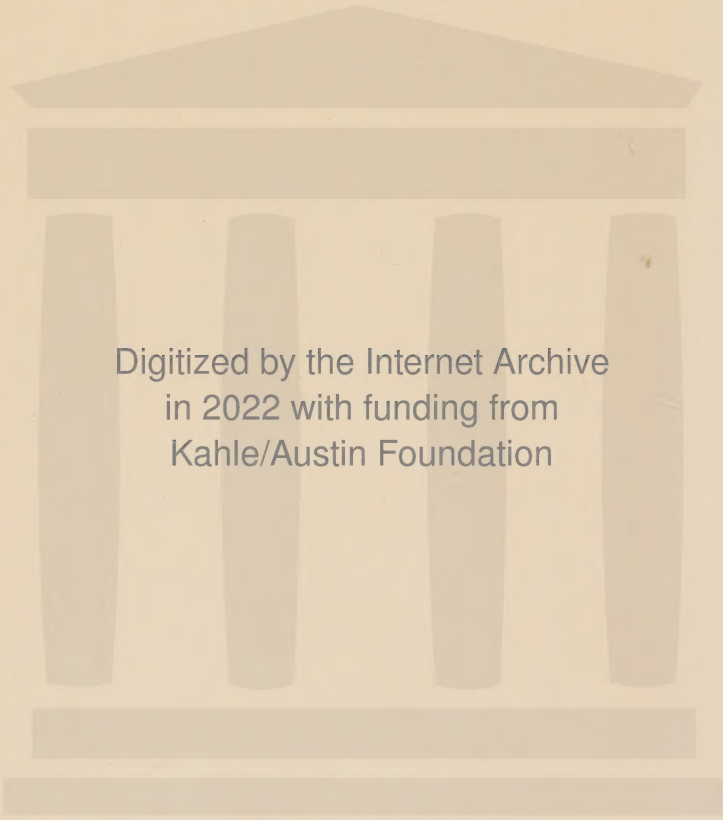
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THE MOBILIZATION

OF

ANKYLOSED JOINTS BY ARTHROPLASTY

BY

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PREFACE.

The creation of an artificial joint by arthroplasty for the purpose of restoring motion to an ankylosed joint is one of the most notable advances of contemporary surgery. Until recent years, surgeons have believed that ankylosis in good position constituted the best curative result to be sought in certain traumatic or infectious joint lesions. With the development of surgical technique and particularly with the advancement of the specialties, operators, alert to the great disability caused by an ankylosed limb, have endeavored to restore motion to the joint by the use of many different operative procedures. The surgical methods devised and practised have shown a logical advance in keeping with the broader understanding of the pathology of ankylosed joints, until finally the method termed arthroplasty was evolved.

An arthroplasty is a highly technical operative procedure, which aims not only to restore motion to a joint, but also to preserve stability. With these two objects in view, the component parts of the joint are reconstructed, and material of some kind is interposed between the articular ends to prevent re-ankylosis.

The clinical and scientific data that has gradually accumulated in the field of arthroplasty has now reached such extensive proportions that it is possible to ascertain the actual status of the procedure. Our object in presenting this treatise is to emphasize the fact that arthroplasty has become a standardized form of treatment for the mobilization of ankylosed joints. Such a conclusion has been reached from our wide personal experience in this field as well as from a careful study of the results reported by the prominent advocates of the method.

Although arthroplasty may be considered a standardized operative measure, its application is still, and probably always will be,

limited. The technique is exacting and can be carried out only by a carefully trained surgeon. Scrupulous judgment must be exercised in the selection of cases for arthroplasty.

In the preparation of this work, we have sought to give credit to all experimenters who have contributed to the process of standardization. The methods of operators that are giving consistently good results have been described in detail with illustrative cases. Bibliographic notes supply definite information as to the specific tests cited.

The writers express their thanks to colleagues whose operative procedures have been included in this work, and who have furnished cases for illustration. The writers are especially grateful to Mrs. Helen Bixby Luchini, who has diligently assisted in the preparation of this work. They also desire to express their appreciation of the courtesy of the publishers of the *Journal of the American Medical Association*, *Surgery, Gynecology and Obstetrics*, *The New York State Journal of Medicine*, *The Boston Medical and Surgical Journal* and the *Long Island Medical Journal*, for permission to reproduce a number of illustrations of the authors' work which appeared in these journals.

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Boston, Mass.

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ARTHROPLASTY.

PART I.

ANKYLOSIS.

TYPES OF ANKYLOSIS.

The term ankylosis denotes a pathological condition involving many different tissues and structures, either singly or in combination. From a practical standpoint, ankylosis may be designated as *periarticular* or *intra-articular*, as determined by the presence of the lesion in the structures surrounding the joint or within the joint itself. If a lesion has been of sufficient extent or severity to destroy a joint, it is customary to find involvement of the periarticular as well as the intra-articular tissues.

This treatise is concerned chiefly with intra-articular ankylosis. The etiology, pathology, diagnosis, prophylaxis, and treatment of this type will be discussed in detail. Periarticular ankylosis will be taken up briefly.

In intra-articular ankylosis, the structures within the joint are involved. The lesions are due either to trauma, or to infection which developed within the joint proper or penetrated into the joint through the blood stream. The pathological changes may be located in the synovial membrane, in the cartilage, or in the bone-ends themselves. In cases of traumatic origin, the formation of callus and fibrous tissue may act mechanically as obstacles to motion.

Periarticular ankylosis is cicatricial in nature. Fixation of this type is caused by adhesions that form during the process of repair following sepsis, hemorrhage, laceration of the capsular and ligamentous structures, or contraction of tissues. Pathological changes in the periarticular structures may also occur secondary to involvement within the joint proper. In the periarticular variety of anky-

losis, the pathology may be localized in the capsule alone, or it may lie in the tendons, tendon sheaths, ligaments, fascia, and even in the muscles. In some cases, the lesion may be entirely extra-capsular.

If possible, a distinction should be made between the periarticular and the intra-articular types of ankylosis, since the method of treatment depends to a great extent upon the location of the pathology. When the periarticular structures alone are involved, non-operative treatment or simple intervention may be a satisfactory measure of relief. Differentiation between the two types of ankylosis usually is not difficult when loss of motion is due to involvement of the periarticular structures alone, or when a bony ankylosis exists. In the periarticular group, the Roentgen film shows a clear joint space, free from all evidences of destruction. In firm osseous union, the Roentgen film shows fusion of the bone-ends. Determination of the pathological focus is difficult, and frequently impossible, when the intra-articular ankylosis is a fibrous or an incomplete bony one, or when lesions are present both within and without the joint. The clinical manifestations cannot be depended upon as a differentiating factor, for some cases of periarticular involvement may retain 5 to 8 degrees motion, whereas others may have a limitation of movement that is entirely out of proportion to the extent of the lesion. Roentgen films are of some value in these cases in that they may show a decrease of the intra-articular space, thinning of the cartilage, and atrophy of the bone and periarticular structures.

The ankylosis may be *fibrous* or *bony,* and either type may be complete or incomplete. Accurate determination of the type and stage of ankylosis is often difficult. Fibrous ankylosis is most often due to a chronic polyarthritic process. Acute septic infections may also result in a fibrous union, usually complete in character. As a rule, the outcome of a tuberculous process is an ankylosis of this type. Fibrous fixation may also be traumatic in origin, resulting either from the organization of tissue following hemorrhage or laceration of the capsular and ligamentous structures, or from the alteration of the joint surfaces due to callous formations. Provided the formation of fibrous tissue is not excessive, motion of 10 to 15 degrees is usually present in the early stage of ankylosis. Later, this motion shuts down until only a few degrees of movement remain.

It often happens in fibrous cases that although no motion can be demonstrated clinically, yet when the joint is opened, the articular line may be traced, and areas of cartilage may be found. Ankylosis in these cases is due to the cicatrization of tissue around the margins of the cartilage and in the capsular space. The cartilage becomes eroded and fibrous bands stretch across the defects, until finally, areas of the eroded cartilage of one articular surface unite with the eroded areas of the opposing cartilage. The slight motion present in many cases of fibrous union subjects the joints to constant strain and static disturbance. Consequently, symptoms develop in these cases, which cause the patient a great deal of suffering and disability.

Bony ankylosis, when complete, is usually the result of a severe infectious process, or of a severe trauma that was followed by excessive callous formation. The first step in the development of a bony ankylosis is the destruction of the synovial membrane and the cartilage. Later these tissues become cicatrized. Erosion may be so extensive that actual bony repair takes place between the articular surfaces. The development of bony ankylosis following joint sepsis is often rapid. Roentgen films assist in the diagnosis of a true bony fixation by showing a fusion of the two bony articular surfaces, a condition that is in marked contrast to the normal state in which a clear joint space is seen between the two articular ends.

A joint firmly fixed in bony ankylosis is not subject to strain, provided the limb is in good position, and provided there are no extensive lesions in the tendons, muscles, and ligaments. Hence, many ankylosed joints are free from symptoms and may be satisfactory even as to function. But should a joint become ankylosed in the position of deformity, the subsequent disability and symptoms may be severe and prolonged, even to the extent of disturbing the entire body mechanism. The subject of the relation of deformity to disability is most important, and an understanding of this principle is vital to the successful treatment of ankylosed joints. (See pages 25 to 32 on The Importance of the Functional Position in the Treatment of Joints.)

Incomplete ankylosis, either fibrous or bony, usually develops when callous formations occur from improper reduction of fragments following trauma. At first, motion is limited by the presence of the callous formation; later, union may take place between the articular ends. Infection may also terminate in an incomplete ankylosis, of the

bony variety. Cases of incomplete union may have a few degrees of motion, but this limited movement is a disadvantage, since it subjects the joint to strain. The Roentgen film is sometimes of help in determining an incomplete bony union.

THE ETIOLOGY OF ANKYLOSIS.

Ankylosis in the great majority of cases is the result of an infectious process or trauma. Other etiological factors that may give rise to limitation of joint motion are superficial scars, prolonged fixation or disuse when a pathological process is going on in a joint, and tissue contraction. Cases of congenital and hereditary origin have been reported, but such sources are too remote to be considered. Infection plays the most important etiological rôle in limiting joint motion. The most common infectious processes are arthritis, tuberculosis, and osteomyelitis. Paramount among these etiological factors is arthritis, a process which may be either acute or chronic in character. The infection may be hemolytic, it may be the result of sepsis introduced directly into the joint, or it may extend into the joint from a focus of disease nearby.

Acute mono-articular arthritis is due to direct infection of the joint proper, occurring frequently as the result of trauma. The etiological organism is usually the streptococcus, the staphylococcus, the pneumococcus, or the gonococcus. The onset of the disease is sudden and its course severe. These acute infections are characterized by marked heat, redness, swelling, pain, a rapid rise in temperature, a rapid pulse, debility, and loss of weight. All motions become limited and painful. The joint is extremely sensitive to jar, and there is spasm on any attempt at movement. The outcome of these acute infections may be either a bony or a firm fibrous ankylosis. Frequently, the capsule and periarticular tissues are damaged to such an extent that scar tissue develops, which in itself tends to limit motion.

The infectious process most frequently found associated with joint ankylosis is the slow, insidious, polyarthritic type, chronic in character. The process is usually metastatic in origin, developing from hematogenous deposits of either attenuated bacteria or toxins. It is often difficult to locate the primary source of infection. The tonsils, teeth, sinuses, or genito-urinary tract may contain the local

focus of the disease. Chronic infections are frequently found in conjunction with trauma of a joint. The symptoms are those of a slow, progressive, infectious process. There is a varying degree of local heat, redness, swelling, and pain, depending upon the severity of the infection and the resistance of the patient. Ankylosis in these chronic arthritic cases results from the formation of adhesions within and without the joint. In the early stage, the fixation is fibrous in character; later bony ankylosis may develop, but the fixation is seldom complete. In the hypertrophic type of arthritis, motion is limited by the presence of osteophytes. These outgrowths cause an alteration in the contour of the cartilaginous surfaces, or they mechanically interfere with motion.

The development of a tuberculous process in a joint is usually secondary to a primary focus in the bone. The infection often terminates in ankylosis—an outcome that is generally considered satisfactory in tuberculous cases, provided the union is an osseous or a complete fibrous one. Unfortunately, the ankylosis that results in many of these cases is an incomplete fibrous union, permitting a few degrees of motion. As a result, the joint is subject to constant strain and static disturbances. There is little hope of restoring function in a joint ankylosed as the result of a tuberculous process, even though the synostosis is complete, because operative interference involves the danger of stirring up any walled-off foci of infection. A firm ankylosis is the preferable result in these cases.

Osteomyelitis, when it occurs in the diaphysis of a bone, may break through into the epiphysis and involve the joint proper. The infection gives rise to profound symptoms. The temperature is high, chills are frequent, and the patient may even become delirious. Unless the joint is treated surgically in the early stages, this virulent intra-articular infection leads to ankylosis, bony in character. Care should be taken that ankylosis occurs with the joint in the best functional position. Operative intervention to restore motion is undertaken with caution, in view of the possibility of the persistence of the infection in an active state for two or three years. Under no circumstances should surgical measures be attempted until two years have elapsed from the initial attack, with no recurrence of symptoms or acute signs.

Ankylosis of traumatic origin is concerned chiefly with comminuted fractures of joints, in which the fragments have been left in

malposition. As a result of imperfect reduction, excessive callus develops. At first, this formation interferes mechanically with motion; later, the changes in the normal articular surfaces and the disturbance in their relation to each other lead to ankylosis, usually of the bony variety. Arthrotomy for the purpose of removing excessive callus does not give gratifying results, the outcome usually being a further limitation of motion. Such joints, when ankylosed, lend themselves readily to mobilization once the acute periarthritis has subsided. In a severe trauma in which the articular surfaces are crushed and the periosteum is torn, bony ankylosis is almost certain to develop.

In many lesions accompanied by intra-articular hemorrhage, bands of cicatricial tissue develop, which cause limitation of motion. Especially is this true if there is any laceration of the capsule or periarticular structures. In fractures complicated by severe hemorrhage, scar tissue as well as callus forms and often unites the periarticular tissues.

Periarthritis is a frequent complication in a traumatic lesion of a joint. In the process of repair a contraction of the periarticular tissues occurs, with the result that motion is limited. The periarthritis may be due to repeated manipulations to gain motion following a fracture-dislocation with wide displacement. Periarthritis may also develop in cases in which there has been considerable cicatrization and tightening of the capsular tissue at the time of injury. In some cases, infection may penetrate into the joint and cause intra-articular ankylosis.

Lesions accompanied by the development of arthritis of the joint proper terminate in limited motion. Not infrequently, infection occurs subsequent to a very slight injury, and the result from an apparently inconsequential lesion is often lamentable.

Other causative agents of ankylosis are scars from burns with or without underlying sepsis; disuse or prolonged immobilization of a joint in which some intra-articular pathological process has been present; and contraction of tissues. An instance of the occurrence of ankylosis as the result of contraction of tissues is found in the fusion that takes place between the tibia and the astragalus, when the Achilles tendon is contracted and limits the dorsiflexion of the foot.

THE PATHOLOGY OF ANKYLOSIS.

The pathology may be termed intra-articular or extra-articular, the differentiation being based upon the location of the pathological changes. The amount of destruction depends upon three factors: The virulence of the infection, the resistance of the patient, and the retention of the infectious organisms in the tissues within or surrounding the joint.

In the development of an *intra-articular ankylosis* of acute infectious origin, the first pathological change is the extravasation of fluid into the joint. The effusion may disappear as suddenly as it occurred, leaving no objective signs; it may recur, or it may persist and increase until ultimately there is pus formation. Tissue changes then take place. The pathogenic organism, which may be the streptococcus, the staphylococcus, the pneumococcus, or the gonococcus, lodges in the synovial membrane, damaging its serous surface. The membrane becomes thick, porky, and infiltrated, and there is edema of its subserous surfaces. In extensive erosion, subserous tissues bridge over the spaces between the serous erosions and adhesions result. The membrane becomes fibrous and transarticular union takes place. If the synovial membrane has been destroyed, the cartilage frequently becomes involved. Provided the damage is limited to the superficial layer of cartilage, its surface may be restored to normal during the process of repair. Should the cartilage become eroded beyond its superficial layer, it is incapable of repair, and union with the opposing joint surface usually occurs. In cases in which the cartilage has been damaged extensively in the primary infection, or at the time of trauma, it is almost impossible to preclude ankylosis. When no vestige of either the synovial membrane or cartilage remains, osseous union inevitably takes place between the opposing articular ends.

In practically all cases of infection of the joint proper, the periarticular structures, in particular the capsule, are involved. This is because the infection tends to escape from the synovial membrane into the adjoining tissues along the vessels and muscular interspaces or subcutaneous tissue.

In intra-articular ankylosis of chronic or subacute infectious origin, erosion is not so common. There may or may not be an effusion of fluid into the joint. Villi form over the synovial membrane, which

becomes covered with a serous membrane. Pannus formations creep down from the membrane. The joint cartilage becomes thin, and later pin-point erosions occur, which in the process of repair are bridged over by fibrous tissue. If this tissue unites with that on the opposing articular end, a fibrous union takes place. Should the infectious process continue, all the cartilage is destroyed, and bony union may result.

When the intra-articular ankylosis is of traumatic origin, hyperplasia of the bone leads to the formation of callus. Especially is this true in severe trauma in which there has been considerable tearing of the periosteal covering with accompanying hemorrhage, and in fractures in which the fragments has been left in malposition.

In the *extra-articular variety* of ankylosis, the pathological changes are cicatricial in character. Adhesions form in the capsule, tendons, tendon sheaths, and ligaments as the result of hemorrhage, tearing of the capsular and ligamentous structures, and tissue repair and contraction. The capsule may be infiltrated, chronically thickened, and adherent throughout the margin of the joint. Adhesions may occur at the junction of the capsule and bone. The pathogenic process, when it is of infectious origin, is similar to that in intra-articular cases. The first change is an extravasation of fluid, which may be secondary to an acute infectious process, static disturbances, or mechanical derangements within the joint proper. If the infection is not severe, the fluid may disappear entirely; if severe, or recurrent, adhesions form in the tissues. A mild infectious process of the periarticular structures may penetrate into the joint, involving first the synovial membrane, then the cartilage, and finally the bone. In traumatic cases, particularly in fractures in which the fragments have been left in malposition, scar tissue forms in the periarticular structures and adheres to the new callous formation.

THE DIAGNOSIS OF ANKYLOSIS.

The diagnosis of ankylosis of a joint is evident from the limitation of motion demonstrated by testing the active and passive movements, but the determination of the exact nature, type, and extent of the ankylosis may offer some difficulty. Careful study of the history may throw some light upon these factors. Manipulations under anesthesia and Roentgen films also aid in determining the true

pathology. Bony ankylosis can be determined with certainty, for it permits no motion, and the fusion is clearly seen in the Roentgen film. Fibrous cases may be difficult to diagnose. Whereas they often permit a few degrees of motion, it is not unusual to find a case in which no motion exists, yet when the joint is opened, a definite articular line with opposing areas of cartilage is found.

From the point of view of treatment, it is important to differentiate between extra-articular and intra-articular ankylosis. Some cases of the periarticular type may be treated satisfactorily by conservative procedure. Discrimination is often difficult, and may be impossible, because the ankylosis exists both within and without the joint.

The value of Roentgen films in the diagnosis of ankylosis may be summarized as follows: The Roentgen film usually demonstrates clearly firm bony ankylosis. The two bony surfaces are united, whereas in the normal joint two distinct articular ends, separated by a clear space, are seen. When the ankylosis is a fibrous or an incomplete bony one, the Roentgen film may show a lessening of the articular space, thinning of the cartilage, and atrophy of both the bone-ends and periarticular tissues. In other cases, the bone alone may show atrophy, while the joint space, the relation of one bone to another, and the periarticular structures appear normal.

THE IMPORTANCE OF THE FUNCTIONAL POSITION IN THE TREATMENT OF JOINTS.

One of the most important principles in the orthopedic care of joints, and one that is often disregarded, is the maintenance of joints in normal functional position during the period of convalescence. This is true of any lesion regardless of its etiological factor. Complete recovery is more probable, and is materially expedited, when joints are treated in the so-called functional positions. (See Part IV on the Prevention of Ankylosis.) In the care of cases that must inevitably terminate in ankylosis, the observance of this principle is vital to the outcome. Not only will the ankylosed joint cause less disability if it becomes fixed in the position of functional strength, but the complications and sequelæ that develop secondary to a deformity of a joint will be avoided. Furthermore, certain joints

such as the shoulder, the hip, the knee, and the wrist, when ankylosed in proper position, are functional.

Given a joint, therefore, in which a destructive process is going on, the first step in treatment is to place the limb in the position that will permit maximum function when ankylosis has occurred. In other words, the joint must be prevented from becoming fixed in malposition. Deformity signifies disability with consequent loss of function. Unless corrected, deformity presages the development of sequelæ which may be far-reaching. Atrophy from disuse, circulatory disturbances, and periarthritis are some of the usual complications. Malposition of a limb often leads to the development of secondary deformities. For example, if the knee is ankylosed in flexion, knock-knee will develop as the result of the strong pull of the outer group of muscles. Deformity may cause complete loss of function in a limb and even seriously involve the body mechanics.

Since it is customary for a patient to assume positions of deformity in seeking relief from pain, stiffness, and soreness, the importance of holding the limb in correct position during the initial lesion cannot be overemphasized. As a matter of fact, relief can be obtained more quickly by maintaining the limb in normal functional position. Let it be understood then, that the prevention of deformity, or its correction as soon as recognized, is fundamental in the care of joint lesions.

The treatment of joints in functional position bears a close relation to the utilization of mobilizing methods in joints. A limb ankylosed in proper position may not be a serious handicap to a person. In fact, in the case of the shoulder, when ankylosis takes place in abduction, the function made possible by the hypermobility of the scapula so closely simulates the function of the shoulder, that stiffness can hardly be detected. Accordingly, certain joints ankylosed in functional position are to be treated surgically only after careful consideration of the value of further motion to the patient. Provided the fundamental principle of treatment of initial joint lesions is appreciated, the field of mobilization is limited.

This phase of treatment is so often neglected that the surgeon is called upon to intercede. It is amazing to see the number of patients who come to our clinics with joints ankylosed in the position of deformity. In shoulder lesions, the arm is often carried in a sling or allowed to hang at the side; hips are stiff in flexion and

adduction; knees are flexed, or even subluxated; and other limbs are held in positions of weakness. Of a series of over 100 ankylosed elbow-joints, not one was seen stiff in the functional position of acute flexion. Had the lesions been treated correctly, it is possible that many of these patients would have had no need to consult a surgeon. Stiffness may be due in a larger measure to treatment of the joint in malposition than to the infectious lesion itself.

The Functional Position of the Shoulder. The shoulder-joint affords an excellent illustration of the advantage of treating a joint in normal functional position. Assume that a severe infectious process is present in the shoulder-joint, the outcome of which may be a stiff joint. If the shoulder is maintained in 45 to 50 degrees abduction, 5 to 10 degrees forward of the sagittal line, the joint, even though ankylosed, will function normally. (Figs. 107 and 108.) This is because the scapula becomes hypermobile and enables the shoulder girdle to move through its normal arc. In downward rotation of the scapula, the arm drops to the side; in upward rotation, the arm can be raised, often to a right angle with the body. In time, the movement of the scapula may so nearly approach the normal function of the shoulder girdle that the ankylosis is not apparent. In view of this function made possible by the hypermobility of the scapula, the shoulder-joint when ankylosed in functional position should rarely be mobilized.

It is unfortunate that the importance of treating this joint in proper position is not more often appreciated. One constantly sees lesions of the shoulder girdle being treated with the arm at the side in a sling or splint. A patient with a chronic arthritis or bursal involvement of the shoulder is allowed to rest in bed with the arm at the side or crossed over the body. Such faulty treatment of the initial lesion may lead to lamentable end-results. The disability and sequelæ following the surgeon's neglect to place the shoulder-joint in functional position are greater than under similar conditions in any other joint. Abduction is limited, and the patient is unable to raise his hand to his head. Serious circulatory disturbances of the elbow, wrist and fingers may occur, especially in senile cases of traumatic origin. Flexion deformity of the wrist may develop while the arm is resting at the side, and in turn, deformity of the fingers may develop secondary to the malposition of the wrist. Briefly, there may be a long period of disability and deformity because of the failure on the

part of the surgeon to appreciate the importance of maintaining the joint in functional position during the initial lesion. In the end, the arm may be absolutely useless for months or years, and not infrequently for life.

The Functional Position of the Elbow.—Recovery from practically every lesion of the elbow is facilitated if the joint is treated in the position of acute flexion. In fact, the only contraindication to treatment in this position is in cases of fractures of the olecranon. Even in these cases, some surgeons are advocating the maintenance of the elbow in acute flexion following early open operation and suturing of the olecranon, in the belief that the period of convalescence is thereby shortened. If both elbows are liable to become ankylosed, it is well to place one in acute flexion and the other in extension.

While it is of advantage to have the elbow become ankylosed in acute flexion—the position enabling the patient to obtain the maximum function—the end-result cannot be considered satisfactory. The arc of motion is extremely limited, and the arm is always in the way. Fortunately, the elbow-joint lends itself readily to mobilizing procedures.

The Functional Position of the Wrist.—The position of strength for the wrist is hyperextension. (Fig. 112.) Unless the joint is treated in this so-called functional position, the patient in his attempt to secure relief from symptoms will hold his wrist in flexion, the attitude of deformity. For example, the chronic arthritic patient who lies bedridden tries to obtain comfort by resting his elbow, wrist and fingers over a pillow. As a result the wrist assumes a flexed position, and in time the deformity becomes fixed.

The consequences of allowing the wrist to become ankylosed in the position of weakness are manifold. Since the hand cannot be used when it is stiff in flexion, atrophy and loss of musculature occur. The power of grip is totally lost. In adults susceptible to arthritis, a swelling static in origin often develops in the wrist and fingers, and in time true periarthritic lesions occur. Flexion deformity of the wrist may lead to hyperextension deformities of the metacarpophalangeal-joints and flexion deformities of the phalangeal-joints.

The Functional Position of the Fingers.—Flexion is the position of strength for the fingers as the power of gripping is thereby preserved. When the fingers are involved, it is necessary to make certain that

ankylosis will occur in good functional position because these joints do not lend themselves so readily to mobilizing methods. As a rule, the injury that leads to ankylosis also damages the tendons and periarticular structures, making mobilization difficult. Not infrequently, one sees subluxation and flexion deformities of the fingers as sequelæ to the faulty position in which the wrist was treated. (See Section on the Functional Position of the Wrist.)

The Functional Position of the Spine.—The treatment of the spine during disease is frequently neglected in reference to the maintenance of proper functional position. All spinal lesions, whether of infectious or traumatic origin, should be treated with the spine in hyperextension. Especially is this important in treatment of the dorsal region. Hyperextension is the position of strength. Yet, strange to say, one rarely sees a lesion of the spine being treated with the joints in the position of correction or overcorrection. As a result the majority of spinal lesions terminate in flexion deformity. The patient suffering from a spinal lesion assumes a position of flexion in recumbency to obtain relief from pain. He finds that a sagging bed contributes to his comfort. When he sits up, he likes one pillow, or possibly two or three, at his back for support. These various means used to secure comfort during convalescence tend to favor the development of deformity, and in time the spine becomes permanently fixed in flexion. This deformity could have been prevented by treating the spine in hyperextension. Furthermore, relief from symptoms could have been obtained more readily by maintaining the spine in functional position.

The sequelæ to a flexion deformity of the spine are serious. The presence of this malposition often leads to the development of a lateral deviation. Such curvature is commonly seen in the round-shouldered and postural defects of children. The relation of this deformity to health, resistance, and endurance is often greater than is generally appreciated. If the lateral deviation remains uncorrected, severe scoliosis develops, the seriousness of which is well known. Structural curves can never be corrected, and it is often difficult or impossible to prevent them from increasing.

Neglect to carry out proper treatment in spinal arthritic lesions is of serious import. The process usually involves several vertebræ and occasionally the entire spine. The end-result of such an extensive lesion is the tying down of the periarticular structures about the

costo-vertebral joints. This change takes place more readily if the spine is treated in the position of flexion. Should ankylosis of the whole spine develop, the ribs become tied down to the spine, making chest expansion impossible. The patient loses weight, and his suffering is expressed in his face. The abdomen becomes prominent and sagging, diaphragmatic breathing sets in, and apical tuberculosis is almost certain to develop. As a rule, death results within two or three years from the onset. By careful hygienic supervision, a fatal outcome may be delayed, but an intercurrent disease such as pneumonia may lead to rapid death. This serious result might have been avoided by maintaining the spine in the position of hyperextension during treatment. Although the periarticular structures may be affected even when the spine is held in correct position, the involvement is never so extreme, and the sequelæ are practically always avoided.

The Functional Position of the Hip.—A hip ankylosed in 5 to 10 degrees abduction, flexion of 10 degrees, and slight external rotation is a functional member. (Fig. 69.) It is only when social or occupational demands are pressing that a hip stiff in this position is mobilized.

Retention of the hip in functional position is often neglected. Ankylosis is practically always seen in the position of deformity, that is, flexion and adduction. A patient suffering from any chronic infection of the hip, even though the symptoms are slight, tends to flex and adduct the limb in an effort to lock the joint and prevent motion. Knock-knee may develop secondary to a flexion-adduction deformity of the hip. Static strains also appear in the feet and legs when malposition of the hip interferes with the line of weight-bearing. A hip ankylosed in flexion is a potent etiological factor in the development of scoliosis, for the shortening of the leg gives rise to a functional curve of the spine, which gradually becomes structural.

The following case which came to my attention demonstrates the seriousness of faulty treatment of a hip lesion.

Case I.—N. P. suffered a tuberculous lesion of the hip-joint. For several years the patient was allowed to walk with the hip in deformity. Examination seven years after the onset showed that a lateral structural curve had developed secondary to the deformity of the hip. (Fig. 1.) It was found impossible to control this curve.

The Functional Position of the Knee. The best functional position for an ankylosed knee is flexion of 5 to 8 degrees. With the joint in this position the patient can walk with an almost imperceptible limp. Although a knee stiff in slight flexion is a comparatively functional member, yet there is a certain esthetic drawback in that one leg is in an ungainly position, particularly when sitting.

FIG. 1.—Case I. N. P. Showing a lateral structural curve that developed secondary to deformity of the hip as the result of faulty treatment of the hip lesion.

Unless precaution is taken following an injury or an infectious process in the knee, the joint will become ankylosed in flexion. When the knee is fixed in this position, secondary deformities are liable to develop. Knock-knee occurs as the result of the strong

pull of the muscles and fascia on the outer side of the leg. In the presence of flexion deformity and knock-knee, subluxation is certain to develop. These secondary deformities interfere with the statics of the entire leg and give rise to symptoms in both the leg and the back. They are difficult and sometimes impossible to correct.

The Functional Position of the Ankle.—For satisfactory function the ankle should become ankylosed at a right angle to the leg, with no varus or valgus deformity. Not only is the function satisfactory when the ankle is stiff in this position, but a good weight-bearing joint is assured. If proper treatment is not carried out, the ankle-joint assumes various positions of deformity depending upon the nature of the lesion. In chronic infections, a patient assumes for comfort a position that leads to the development of talipes valgus and toe-drop. Valgus is more serious than any other deformity, for when the foot is in this position, the motion of the ankle-joint is limited and inversion may be entirely lost. The position of the foot causes the gait to be awkward, and the deformity gives rise to constant strain.

The Metatarso-phalangeal-joints.—These joints, with the exception of the first metatarso-phalangeal-joint, rarely become ankylosed. When the great toe is likely to become stiff as the result of injury or infection, the best position for the joint is straight, without abduction or adduction. The great toe in this position is most adaptable to mobilizing measures, which are always advisable in the treatment of this joint.

THE TREATMENT OF ANKYLOSIS.

The methods used in the treatment of ankylosis have shown a logical advance that is in keeping with our increased knowledge of the etiology and pathology of joint fixations. In the utilization of early methods, many of the factors that influence treatment were not taken into consideration. Little was known of the etiology or nature of the ankylosis, or of the localization of the pathology. At the present time, owing to our ability to determine the important factors pertaining to ankylosis, it is possible to direct treatment against the particular structures involved. There are several methods in use today which may be carried out with the assurance of obtaining a good result.

Early Methods of Treatment.—Previous to 1860, the general method of treatment was "brisement forcé." This procedure is still in use and in properly selected cases gives good results. (See Modern Methods of Treatment.)

The idea of treating ankylosis by the formation of an artificial joint originated with an American, J. Rhea Barton,[1] of Philadelphia. In 1826, in a case of ankylosis of the hip-joint, he performed an osteotomy through the great trochanter and part of the femoral neck, and subsequently carried out manipulations to prevent recurrence of the fixation. For two years after operation, the limb had good function; then ankylosis recurred, due undoubtedly to the patient's intemperate manner of living.

In 1840, Rodgers,[2] of New York, modified this method by removing a disk of bone from between the trochanters. Three years after operation the patient had excellent motion. Bérard,[3] inspired by Barton's procedure, was the first to suggest its application to temporo-maxillary ankylosis, but he himself did not practise such a method. To Esmarch[4] belongs the honor of having expounded the true theory of this method. The same principles were devised by Rizzoli,[5] in 1857, but he did not make known his theory. Verneuil,[6] Bruns,[7] Dieffenbach,[8] and other names are connected with early operations of this nature.

Attempts were made to break up adhesions by chiseling, but such methods were rarely successful.

Wolff[9] recommended a surgical measure to which he gave the name arthrolysis. This procedure consisted of dividing all fibrous and bony adhesions by chiseling, and restoring the articular extremities to their normal position, without resection. Wolff obtained favorable results in 9 cases, 4 of which were fibrous in nature and 5 bony. It is probable that he did not treat a true bony ankylosis. This same method was used by Kocher,[10] but he supplemented it by dislocation of the joint for a short period following arthrolysis.

Transplantation of joints has also been tried in treating ankylosed limbs. Lexer,[11] who has had the most experience in this field, believes that the method of transplantation has been superseded today by the arthroplastic procedures, which more nearly approach the goal of restoring motion. Transplantation of joints is applicable only when the joint defect, in particular a freshly operative joint defect, is very extensive. It is obvious that this procedure is radical

and attended with risk. Not only is it difficult to ensure the maintenance of homoplastic material, but even if the transplant is retained, it is unlikely that the new joint can be controlled sufficiently to obtain satisfactory function. Such a method will never be generally accepted.

Modern Methods of Treatment.—The method used in treatment depends upon the structures involved in the ankylosis. If the fixation lies outside the capsule, plastic elongation of the tendons and muscles may be performed. When accurately done, this procedure restores function. If there is union of the tendon to its sheath as the result of a tendo-synovitis, the tendon sheath should be excised, and the tendon then protected by covering it with a flap of connective tissue well supplied with fat, or with the aponeurosis of a muscle. Cicatrices should be excised, and large cutaneous flaps with layers of fat attached should be inserted in their place.

In the treatment of intra-articular ankylosis, in which we are primarily interested, the methods in use today are: Manipulation, resection or excision, and *arthroplasty*.

Manipulation.—Manipulation gives promising results in stiff joints with 15 to 20 degrees of motion, in which the limitation of movement is due to fine adhesions. This method is particularly adaptable to the knee and the shoulder. Manipulations should never be carried out until all acute periarticular signs of swelling, heat, and sensitiveness have disappeared. During the acute reaction following manipulation, the joint is maintained in proper anatomic position. When the acute symptoms have subsided, gentle passive and active movements are carried out.

Manipulation is a measure that must be used with great caution, for considerable damage may be done by forcible and repeated manipulation to gain motion. Stretching of the joint is of no value if the involvement is a firm fibrous one, or if there is union between the joint surfaces. Manipulation in such cases simply causes a breaking up of adhesions, followed by a reaction so intensive that there is extravasation of fluid into the joint proper and into the periarticular structures. On the day following the manipulation, the joint is sensitive and painful and cannot be moved. The result is that the suffering of the patient is increased temporarily, and no relief is obtained until re-ankylosis takes place. It is our belief that manipulations in these cases tend to lead to the development of

ankylosis. One often sees an elbow becoming stiff following a fracture. Roentgen films show the fragments perfectly reduced, but because the motion begins to shut down, the surgeon worries over the outcome and advises manipulation. The result invariably is less motion. We advise keeping these joints at rest in bandages or slings until acute swelling, pain, and sensitiveness have subsided. The patient may then begin voluntary movements under supervision. The joint should never be forced and movement should be stopped if painful.

Resection or Excision.—Resection or excision is a method that traces back to the early treatment of ankylosed joints. In 1843, Textor[12] reported a case of ankylosis of the elbow in which this method was used. Among the early advocates of the procedure were Ferguson,[13] Czerny,[14] Sayre,[15] and Defontaine.[16] König[17] recommended resection with wide luxation. Cavazzani[18] advised a transverse incision and sparing of the bone and soft parts. Dartignes[19] described a trochleariform osteotomy, in which he resected the joint surfaces with preservation of their natural form. The method of resection was especially worked out by Ollier[20] and his followers in the Lyonnaise School. There are many advocates of Ollier's procedure in France today, most prominent among whom are Santy[21] and Leriche.[22]

Insofar as function is concerned, excision undoubtedly increases the motion of the joint. But when sufficient bone has been removed to permit easy motion, there is the possibility that the mobilization will result in a flail joint. Stability is more essential to a joint than motion. Because the resection method fails to take into consideration this important feature—stability—we believe it has no place in the mobilization of joints. The discrimination between an excision and an arthroplasty is an interesting subject, which is discussed fully in Part II.

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PART II.

ARTHROPLASTY.

In general terms, an arthroplasty is the creation of an artificial joint for the purpose of restoring motion to a joint which is either completely ankylosed, or which has such a limited degree of motion that the limb is not serviceable. Under the heading *arthroplasty* might be grouped all operations, regardless of the nature of their technique, which have for an object the increasing of the motion of a joint. In recent years, the term arthroplasty has come to be used in a restricted sense. The procedure is defined as a highly technical one that aims to restore motion by reconstructing the component parts of the joint, and by interposing a substance between the articular ends to prevent re-ankylosis, and to act as a substitute for the normal cartilage lining.

An arthroplasty, to measure up to its true standard, not only must increase the arc of motion in a joint, but it also must preserve *stability*. Whereas the value of other mobilizing methods may be estimated according to the mobility obtained by operation, the intrinsic worth of an arthroplasty depends far more upon the retention of stability and firmness than upon the return of motion to the normal arc. A joint is functional only when it is stable. The true test of an arthroplasty lies in positive answers to the following questions: Is there sufficient motion in the joint to increase function? Is the motion painless? Is the joint stable? An arthroplasty that does not measure up to these requirements is not a success.

ARTHROPLASTY NOT AN EXCISION.

A sharp distinction may be drawn between an *arthroplasty* and an *excision*. The advocates of the resection operation pay no regard to stability. The procedure involves the removal of a sufficient amount of bone to allow free play between the articular surfaces, with the result that the joint is hypermobile in all directions.

Motion in the presence of such instability rarely improves function. The joint is subject to constant strain, and in time a hypertrophic arthritis develops.

The followers of excision contend that in many instances this procedure gives as good results *functionally* as a true arthroplasty. There is no doubt that the increase of motion following a resection is considerable, but is stability preserved. The postoperative results of excision that have come to our attention have always been flail joints. In the elbow cases, the joints have been weak and often required external support in the form of a leather armlet with limited motion. In the weight-bearing joints, the important feature—stability—was lacking. It is our opinion that excision has no place in surgery for the mobilization of joints.

METHODS OF ARTHROPLASTY.

All methods of arthroplasty have in common the exposure of the joint surfaces, the remodeling of the articular ends, and the interposition of some material. As the anatomic-morphological changes that contribute to the formation of a new joint have come to be better understood, the material used by operators for interposition has differed in nature. Likewise, as the value of stability in a joint has come to be more fully appreciated, there has developed a precision in remodeling that aims to preserve stability. Modern methods of arthroplasty, therefore, differ from the earlier procedures in two respects, first, in the substance used for interposition, and secondly in the exactness of the remodeling of the joint-ends.

Early Arthroplastic Methods.—*Foreign heterogeneous substances*, both absorbable and non-absorbable, have been used for transplants. Carnochan[1] in performing an operation upon an ankylosed jaw used a piece of wood to keep the bone-ends apart. Various other foreign materials have been tried, including gilded aluminum plates (Orlow[2]), magnesium plates and silver (Roser[3] and Hübscher[4]), temporary packings of gauze, celluloid, and gutta-percha.

Chlumsky[5] conducted a large series of experiments, using both absorbable and non-absorbable materials. In his early experiments he tried plates of celluloid, silver, zinc, rubber, and layers of collodion. Later he used such substances as ivory, magnesium, and decalcified bone.

Ankylosis ultimately recurred in all the cases in which foreign materials were used. There was always inherent danger of suppuration from the interposition of foreign bodies into the joint. As a rule, non-absorbable substances were extruded from the joint. These various materials are no longer used, and our interest in them is chiefly historical.

Animal membranes have been used for flaps. Föderl,[6] in 1895, interposed flaps of animal membrane and walls of ovarian cysts. Suppuration developed, and ankylosis recurred in these cases. Diel,[7] in 1913, reported a case of femoral-patellar ankylosis in which he inserted a flap of reindeer tendon and the epiploön of a rabbit. Ten months after operation, the patient could walk well without support.

The use of chromicized pig's bladder for the interposed material has given particularly successful results. This method was devised by Baer.[8] It is still carried out today and ranks second in use to the free fascial flap procedure. (See Modern Methods of Arthroplasty, p. 41.)

Substances of human source were tried as flaps in the hope of obviating the risk of sepsis and the extrusion of the material from the joint. In accordance with our knowledge that an artificial joint is produced when fascia, periosteum, cartilage, or muscle covers the unreduced fragments in cases of fractures, these substances came to be used for interposition. Verneuil[9] was among the first to suggest the possibility of interposing soft parts into the joint.

Rochet[10] covered the ends of the resected bones in various joints with periosteal flaps. Hofmann[11] secured good results in several cases with the use of this material. Grierfenhagen[12] reported three arthroplasties of the elbow-joint in which periosteum was used. He did not give details of his results. Payr[13] and von Frisch[14] were unsuccessful in their attempts to use periosteal flaps. In general, the interposition of periosteal transplants has not proved satisfactory, doubtless because of the fact that periosteum tends to degenerate rapidly.

Joint cartilage was tried to some extent, and several successful results were reported. It was first used by Tuffier,[15] in 1901, in a comminuted fracture of the upper end of the humerus. Perfect function resulted. Jacob[16] reported an operation performed according to Tuffier's method in a case of subcoracoid luxation. Thirty-

six days after operation, almost all movements of the arm were possible. Weglowski,[17] in 1907, reported a case of ankylosis of the elbow, in which he used successfully a layer of cartilage which had been taken from a rib. Klapp[18] applied flaps of cartilage in 2 cases of elbow ankylosis following fractures. The results were excellent, the patients recovering nearly the entire amplitude of movement. Klapp also secured good results in 2 arthroplasties of the shoulder in which he used Tuffier's method.

Deutschländer,[19] basing his technique upon Klapp's principles, mobilized an ankylosed knee by resecting the anterior part of the condyle and interposing a pedicled flap of cartilage. He obtained active extension to 170 degrees and flexion to 130 degrees.

Mauclaire[20] used cartilage from the astragalus to cover the rough bone-ends in an ankylosed elbow. Roentgen films taken after operation showed the cartilage fused to the bone. Judet[21] was the first to study experimentally the transplantation of cartilage. From several experiments he concluded that the joint cartilage, when it is separated from an organism and reapplied to a structure that has been properly selected, has the power of uniting and continuing to live. He noticed that a purely cartilaginous fragment united with difficulty, but that when it was reënforced with a layer of bone, union followed in the majority of cases. (This step finally led to the transplantation of entire joints.)

More recently, Delagenière[22] concluded from a study of cartilage grafts that a stable joint could not be obtained by their use. The interposition of cartilage flaps has now been practically discontinued.

Transplants of true skin also have been tried. Gluck[23] reported a case of bony ankylosis of the temporo-maxillary articulation in which a cutaneous flap was inserted. After the wound healed, the mouth could be opened to its maximum. Tietze,[24] in 1923, reported 3 cases of ankylosed elbows in which he used cutaneous flaps with success.

Muscle furnished another source of material. The modern method of arthroplasty, in which a fascial or fatty flap is used, may be said to have its origin in the interposition of muscle. Helferich[25] seems to have been the first to make a practical application of the muscle flap method. In 1893, he exhibited a child who had gained motion in the jaw following the removal of a relatively small piece of the condyle of the lower jaw along with the periosteum, and the

insertion of a pedunculated flap of temporal muscle. At about the same time, Lentz,[26] Henle,[27] and others practised muscle implantations in jaw resections.

Various modifications of these early attempts at muscle implantation continued to be carried out in ankylosed jaws. Bilczynski[28] reported an operation that was performed by Krajewski in which both the coronoid process and the condyle of the inferior maxillary were removed, and a flap of the temporal muscle was inserted. Hoffa[29] reported a case in which a similar method was used. Kusnetzoff[30] practised the methods of Hoffa and Bilczynski, using a flap from the masseter. Rochet[31] and Schmidt[32] performed osteotomies of the ascending branch of the lower jaw and interposed a piece of the masseter.

Operations upon other joints followed those of the jaw. Quénu[33] was the first to use muscle implantation in an ankylosed elbow. Following a sparing resection, he interposed the anterior ligament reënforced with fibers of the brachialis anticus. Albarran,[34] Nélaton,[35] Delbet,[36] Hoffa,[29] Schanz,[37] and Murphy[38] also mobilized elbows, using flaps from the muscles contiguous to the joint. Berger,[39] in 1903, reported a case in which he inserted a flap of the anconeus.

Muscle flaps were also used in arthroplasties of the hip and the knee. Rochet[31] and Nélaton[35] reported arthroplasties of the hip. Cramer[40] applied the method in ankylosis of the knee, and reported 7 cases of ankylosis of the patella in which flaps from the vastus internus were interposed. Six operations were successful.

All these early attempts involving the use of muscle flaps have been studied at length by Huguier[41] in his thesis on the treatment of ankylosis.

The chief objection to muscle as the interposing substance is that it is bulky, and therefore requires the removal of a large amount of bone. Muscle also undergoes degeneration rapidly.

Silver impregnated fascia has been suggested as a suitable material by Allison and Brooks,[42] who believe that fascia when treated in this manner causes no inflammatory reaction. Magnuson and Coulter[43] used this substance in an ankylosed elbow and obtained an excellent result.

Modern Arthroplastic Methods.—The methods enumerated above, with the exception of that in which chromicized pig's bladder

is used as the transplant, are practically out of use at the present time. Now and again isolated cases are reported in which flaps of cartilage, periosteum, skin, silver impregnated fascia, or muscle are used, and we are hearing of attempts to revive the use of celluloid. On the whole, however, grafts of such substances have been superseded by flaps of fascia.

The credit for the development of the fascial flap method is due to the late John B. Murphy,[44] of Chicago, who was more persevering than any other surgeon in his endeavor to restore motion to ankylosed joints. The method devised by Murphy has formed the basis of the great majority of modern arthroplastic measures.

The essential feature of the Murphy operation is the insertion of a pedicled flap of fascia and fatty tissue taken from the vicinity of the operated joint. Murphy believed that the transplant received its nourishment through the pedicle. He also placed a great deal of emphasis upon the inclusion of a considerable quantity of fatty tissue, for he believed that the fat aided in laying the foundation of the new joint by forming an hygroma bursa. The technique of the Murphy operation varied as necessitated by the anatomic structure of each joint. Murphy was most successful in treating ankylosis of the hip-joint. The technique of arthroplasty of this joint will be found in detail under the section treating the hip.

The fundamental changes that have taken place in the technique of arthroplasty since the Murphy method was perfected are the *omission of the pedicle* of the flap, and the use of *free fascia lata* without the inclusion of fatty tissue. Careful study and experimentation have led to this development. In the first place, experimenters proved that the flap did not receive nourishment through its pedicle. Furthermore, it was demonstrated both experimentally and clinically that free flaps of fascia remained viable after transplantation. Kirschner,[45] and Kostenko and Rubaschew[46] used free fascia to replace abdominal fascial defects, to reënforce sutures, and to consolidate reconstruction of walls. Kirschner reported 10 cases in which he used free flaps successfully. They healed without reaction, and several months after intervention, they had retained their structure and were viable. The omission of fatty tissue obviated the dangers of embolus and fatty necrosis, which are likely to be encountered in dealing with this substance.

The use of free fascial flaps has certain advantages over the implantation of pedicled flaps. The free transplant requires only a small dissection for its removal. Hence, the structural support of the joint is in no way disturbed, and perfect stability is assured. Free flaps are more easily handled and they require less space for insertion than the pedunculated flaps.

The application of free fascial flaps in the field of arthroplasty has been studied especially by Kirschner,[45] Payr,[47] Putti,[48] Campbell,[49] and the writers.[50] Groves,[51] Dickson,[52] Monjardino,[53] and others have also contributed to the work with free grafts. Kirschner[45] was the first to propose the use of free fascia in joint mobilization. At his inducement Payr,[54] in 1910, performed an arthroplasty of the knee using a free fascial flap. Within the next few years, Payr, Putti, Rehn,[55] Ritter,[56] and the writers also tried the insertion of free fascial flaps in joints.

Insofar as the writers' early use of the free flaps is concerned, we had already used a free transplant in an arthroplasty before the work of the early experimenters in Europe came to our attention. The story of this first case is an interesting one. We had read, with a great deal of interest, an article on an experimental study of free fascial transplants in dogs, published by Davis,[57] in 1911. The following year we were asked to perform an arthroplasty before the New Hampshire State Surgical Club upon a case of double ankylosis of the elbow, which had resulted from septicemia. We planned to transplant a flap of fat and fascia from the triceps according to the Murphy method. Previously we had performed this operation in our ankylosed cases. We found that the patient's arm during the acute septic process had had 15 to 20 discharging sinuses, with the result that, although they were entirely healed, the fat over the triceps had disappeared in the process of recovery. The patient had to be relieved, and we were scheduled to go ahead and operate! There occurred to us the possibility of using a free fascial transplant as suggested in the Davis article. Accordingly we made a good exposure, cutting the olecranon; remodeled the articular ends; and inserted a piece of fascia which was removed from the thigh. The technique used was very nearly the same as that which we use today. The wound healed by first intention, and the patient recovered motion in his elbow. Two years later we performed an operation upon the other elbow. When we last heard from the patient, about

ten years after the second operation, he had resumed his former occupation as a lumberjack.

The methods of arthroplasty in use, although essentially alike in principle, have their slight differences in technique. Some operators emphasize the removal of a large amount of bone; others recommend a sparing resection. One group of surgeons advocates following the anatomic contours in modeling the new joint surfaces. Another group, knowing that it is impossible to duplicate exactly the normal surfaces, advises a technique that aims to restore function and stability by a mechanical remodeling, a principle that ignores entirely the natural outline of the joint-ends. The majority of operators prefer to use flaps of fascia alone, but there are a few surgeons who have more success with a flap of fascia and fat, and in Kukula's Clinic (Jirasek,[58] Knazorzouicky[59]) omentum from the abdominal cavity is used.

Payr[60] advises excision of the vascular connective tissue and any altered cartilage, a step which he believes helps to prevent re-ankylosis. He also recommends the extirpation of the capsular tube leading to the nerve endings, in addition to the removal of the masses of connective tissue, because of possible inflammatory changes in the capsular ligamentous apparatus. It is Payr's opinion that a new capsular tube develops from the periarticular connective tissue when simple mechanical exercises are carried out. We take exception to the removal of the capsule, for in our opinion, the presence of this structure is the surest guarantee of stability. We believe that the new joint should be constructed in such a way that the capsule can be closed in over it. Extirpation of the capsule is almost sure to result in an unstable joint with lateral mobility. Payr has obtained his best results with fat and fascial flaps, used either with or without a pedicle. Payr emphasizes the importance of including plenty of subcutaneous fat, as he does not approve of laying the fascia, bare of fat, directly over the joint.

The methods of Putti[48] and Campbell[49] differ from that of the writers in technical details of exposure and remodeling. Free fascial flaps, such as are recommended by the writers, are used in both Putti's and Campbell's methods. Putti has been particularly successful in his arthroplasties of the knee-joint. (See Section on Knee Arthroplasty.) Campbell has been very successful in his hip cases. (See Section on Hip Arthroplasty.)

The Writers' Method in General.—A careful preparation for arthroplasty is very important. The operative field, including not only the joint involved, but also one joint above and one joint below the affected member, is given a two-day preparation. At the same time, the field is made ready for securing the fascial flap. If the upper extremity is to be mobilized, the fascia is removed from the leg on the same side of the body as the ankylosed joint, and this leg from the hip to the knee is prepared; if the knee or hip is to be mobilized, the fascia is taken from the opposite leg, which is prepared from the hip to the knee. We follow this procedure because we believe it best to minimize the operating field on the ankylosed leg to avoid disturbing the external support of the joint.

Ether is the usual anesthetic. In some cases in which its use is contraindicated, recourse to a spinal anesthetic is necessary. At the time of operation, a tourniquet is applied and an application of iodine made to the skin. An incision that gives a good exposure of the joint is made. The skin-edges are clamped off with towels to avoid handling the skin during operation. When the joint has been exposed, a careful study of it is made from Roentgen films.

In breaking down the ankylosis, one should try insofar as possible to follow the contour of the old articular surfaces. A sufficient amount of bone is then removed from each surface to allow free motion. This is a very important step in the operation for if too much bone is removed a flail joint will result. New articular surfaces are carefully modeled to conform as closely as possible to the natural contours of the bone-ends. The joint surfaces must fit accurately, and there should be no hitch in the motion. Extreme care must be taken to preserve stability. In the preparation of the joint-ends, all periosteum is removed.

The next step is the dissection of the fascial flap from the leg. An incision is made on the outer side of the thigh slightly below the middle. The fascia nearest the knee on the outer side of the leg is thickest, and therefore most serviceable. A flap of fascia, free from fat, and of sufficient size to cover the resected bone surfaces, is removed. In interposing the flap into the joint we place the glistening, smooth part out, and the side on which the fat was attached against the raw surfaces of the bone. The flap is attached with interrupted chromic catgut sutures No. 2.

The articular surfaces are approximated. The capsule is sutured.

The skin wound is closed, and dry sterile dressings are applied. The limb is then placed in a plaster bandage or splint in proper position.

After-treatment.—The ultimate success of an arthroplasty depends to a great extent upon the efficiency of the after-care. The patient should be under observation for a long period. Roentgen films should be taken frequently in order that the operator may observe the bone changes in the joint.

There are two important principles in the after-treatment. First, the joint must be protected against strain. Hence, overuse or attempts to put the joint through arcs of motion that will bring tension on the tissues before convalescence is well established must be avoided. The best guide in the regulation of mobilization is pain, in the presence of which motion should never be attempted. The second principle of after-treatment is the prevention of atrophy of the bones and musculature. The structures are kept in good condition by stimulating the circulation by the use of heat, massage, and gentle passive motions.

Traction is an essential of after-treatment, and its purpose is three-fold. It is possible that traction, by increasing the space between the bone-ends, acts as an adjunct to the interposed flap of fascia in preventing the development of a fibrous union. Traction also aids the formation of a more relaxed capsule. By the use of traction it is possible to begin painless motion early, a factor that is of importance in the formation of a joint cavity, and in preventing atrophy.

The intrinsic traction apparatus devised by White[61] has been found most useful, not only because of its accuracy in measuring the amount of traction, but also because of its convenience. A Thomas ring splint forms the basis of the apparatus for knee and hip cases, and the Jones humerus extension splint forms the basis for elbow cases. By combining the Pearson knee attachment with the Thomas splint, or supplying a joint at the attachment of the forearm piece in the humerus splint, the patient can regulate the motion himself by a line and pulley arrangement. (Fig. 2.)

Passive motion is started when the traction is applied, usually about a week or ten days after operation. At first the movements are carried out very gently only two or three times a day, and are later gradually increased. Pain and sensitiveness are the best guides in the regulation of the increase of motion. There is little

danger of excessive strain if the patient himself is able to control the motion. Active exercise is begun as soon as conditions are favorable for further mobilization. No weight-bearing should be allowed until the ligamentous structures have tightened.

FIG. 2.—Intrinsic traction apparatus showing pulley arrangement by means of which the patient can guide passive motion at the knee-joint.

Lexer's[62] Method of Arthroplasty.—The primary difference between Lexer's method and other modern arthroplastic procedures lies in the nature of the material used for interposition. Lexer prefers flaps of fatty tissue instead of fascial transplants. He finds that the fatty flap by fitting snugly into all irregularities of the joint surfaces stops bleeding and hence prevents the formation of adhesions. Also, the freed fat acts as a lubricant to stop clotting. It is his opinion that fascia, on the other hand, being a thin substance requires exact patterning to the articular surfaces to prevent the accumulation of blood. The fatty flaps are secured from the posterior lateral side of the thigh.

Lexer had developed his method even before Payr used the fascial procedure in his first case. In 1905, Lexer suggested the use of a pad of fat in operation upon an ankylosed jaw. In 1906, he used the procedure in 2 cases of elbow ankylosis. Since 1910, Lexer has

used his method regularly, and he has obtained many successful results.

Baer's Method of Arthroplasty.[8]—Aside from the various methods of arthroplasty in which human substances, either free fascial or fatty flaps, are used for the interposing material, there is one other method that is giving good results. Baer is reporting success with the use of chromicized pig's bladder as the medium. This membrane is thin and flexible, it conforms accurately to the surfaces of the modeled bones, and it withstands disintegration for a period of forty to fifty days. The objections that have been raised against the use of this substance because of its irritant qualities, and the possibility of its sloughing, seem to have been overcome by cutting down the chromicization. Baer finds that, with the chromicization reduced, there is no longer any intensive chemical reaction on the surrounding tissues, and there is seldom a case of sloughing. Baer has been particularly successful in treating the hip and the jaw. (See Sections on the Hip and the Jaw.)

Preliminary Correction of Deformity and Removal of Cicatrices.—Occasionally the deformity of an ankylosed limb is so extreme that its correction is necessary before an arthroplasty can be performed. For instance, if the hip is ankylosed in marked flexion and adduction, the deformity may necessitate correction by a preliminary procedure; otherwise, an arthroplasty would present a very difficult operative problem. Marked flexion of the knee, if long-standing with contraction of the posterior capsule and hamstrings, may also require preliminary intervention. All cicatrices should be excised before arthroplasty is attempted.

Complications.—Sepsis resulting from surgical interference is practically the only complication. It is readily appreciated that an arthroplasty is a major operation—one that requires the exposure of a large amount of tissue and the handling of several body parts. The uncovering of avenues of infection often is beyond one's control. Precise technique, non-traumatic in character, with perfect regulation of the bleeding helps to obviate the danger of infection.

In an occasional case there is seen extreme hypersensitiveness of tissue during attempts at passive motion, although the technique of the operation was apparently perfect. From our experience we conclude that such hypersensitiveness is due to the presence of residual infection in some other part of the body. In two instances we have

seen such a condition resulting from acute tonsillitis, in one case from an acute appendix, and in other cases from dental abscesses. If these complications are to be avoided, not only the local condition of the joint must be carefully considered, but also all possible sources of infection, such as the tonsils and teeth, must be checked and eradicated.

INDICATIONS AND CONTRAINDICATIONS.

The selection of cases suitable for arthroplasty is extremely important, and any surgeon who attempts to use this method of mobilization must exercise scrupulous judgment in its application. There are definite general and local considerations upon which to base the decision to mobilize a joint. Of prime importance is the disability that a person endures on account of the ankylosed joint. The surgeon must decide if the stiff member seriously incapacitates the patient. Many joints, if ankylosed in good functional position, cause very little inconvenience, and such a joint should not be mobilized unless the patient's occupation depends upon his having more motion in the limb. In the jaw, where disability interferes with life itself, arthroplasty is a matter of necessity rather than of choice.

The functional positions for the different joints, in brief, are: The shoulder in abduction of 45 to 50 degrees, 5 to 10 degrees forward of the sagittal line; the elbow in acute flexion; the wrist in hyperextension; the spine in hyperextension; the hip in 5 to 10 degrees abduction, 10 degrees flexion, and slight external rotation; the knee in flexion of 5 to 8 degrees; and the ankle at a right angle to the leg. (See Section on The Importance of the Functional Position in the Treatment of Joints.)

Once it has been determined that the patient's disability warrants an attempt at mobilization, other factors must be considered. Is the joint one that will lend itself well to arthroplastic measures? What is the origin and the nature of the ankylosis? If of infectious source, what was the character of the process? Is the disease quiescent? Are the circumstances of the patient from a social and occupational standpoint favorable? These are the problems presented for consideration.

All joints do not lend themselves well to arthroplastic measures. There are practically five joints in which mobilization is justified—

the temporo-maxillary joint, the elbow, the knee, the hip, and the first metatarso-phalangeal joint. In only very rare instances are the shoulder and the wrist subjects for mobilization, and under no circumstances is arthroplasty to be considered in the ankle-joint. Occasionally it may be advisable to mobilize the fingers.

It is universally agreed that the elbow is the most satisfactory joint to mobilize. In our clinics we have performed a large series of elbow arthroplasties, and excellent results have been consistently obtained. Mobilization of the knee and the hip is generally admitted to be more difficult. In the past, the number of knee and hip arthroplasties reported by any one surgeon has been small, and the percentage of failures high. At the present time, larger series of cases are being reported, which include a greater number of good results. Much yet remains to be done in the field of arthroplasty of the knee and the hip. At the present stage of development, there is more than a reasonable chance of a successful outcome, provided the case is carefully selected, the operation performed with extreme care, and the after-treatment assiduously carried out. Arthroplasty of the metatarso-phalangeal joint is considered a routine procedure, which gives excellent results in practically all cases.

The fundamental indications for arthroplasty may be summarized as follows:

Major Joints.—Two stiff elbows require arthroplasty of one elbow or possibly both. Two stiff hips present the same indication. Two stiff knees indicate mobilization of one side at least. Combinations of ankylosed hips and knees in the same person, a condition not infrequently seen following multiple arthritis, present definite indication for arthroplasty of one or more joints. In an occasional case arthroplasty of the shoulder is indicated.

Minor Joints.—The jaw necessitates mobilization. Very rarely arthroplasty is indicated in a wrist. Occasionally the fingers may be mobilized.

The Origin of Ankylosis.—The determination of the cause of ankylosis is essential. The best results from arthroplasty are obtained in cases of purely traumatic origin. Mobilization may be considered in cases of infectious origin, either acute or chronic in nature, provided the process is not active and provided there is no sign of a progressive infectious disease. A low-grade polyarthritic process is a contraindication to arthroplasty. In such cases of

increasing disability, there would be no advantage in performing an arthroplasty, since the restoration of motion would be of little use to a patient who would undoubtedly be bedridden.

Arthroplasty should never be attempted while an acute pathological process is still going on in a joint. Sufficient time should have elapsed from the acute flare-up of the septic process to assure complete eradication of the original infection. If intervention is made too soon, there is always the possibility of the recrudescence of infection. Operation usually is not advisable until one and a half or two years after all signs of infection have disappeared. In our clinic, we place the safe period at one and a half years if the infection has involved only the tissues, and at two years if the bones have been affected. Most surgeons have reached the conclusion as to the favorable time for operation from observing a large series of disastrous results that followed intervention, six or eight months after injury, in cases of fracture with non-union from sepsis.

Although it is imperative to postpone operation until the infectious process is quiescent, it is also important not to delay intervention too long, as atrophy of the soft parts is likely to develop from disuse. The return of motion following operation is then rendered more difficult.

Ankylosis of the gonorrheal variety lends itself more readily to arthroplasty than synostosis due to other infectious processes. Care must be taken, however, not to perform the operation too soon in cases of ankylosis resulting from Neisserian infection, for the complications of periarticular swelling and edema, which are usually present, recede slowly.

Mobilization of joints ankylosed as the result of a tuberculous process should be advised with extreme caution, for there is always the possibility of stirring up latent infection by a radical procedure. Tuberculous joints even though fixed in firm union may retain small walled-off foci throughout life. Very rarely, surgeons have mobilized selected cases of tuberculous origin, in which the health was excellent, and in which there had been no evidence of an active process for years. We mobilized one such case of the elbow and obtained an excellent result. In spite of the good outcome reported in some of these cases, we are unwilling to advise arthroplasty in tuberculous cases, except when the disability is extreme, and then, only when the process has been quiet for many years.

Certain infections cause a great amount of destruction of the bone, and injury to the soft structures of the joint. When such destruction is present, a difficult operation may be expected. Marked scarring of the periarticular tissues also complicates operative procedures.

Nature of the Ankylosis.—The osseous variety of ankylosis, and the fibrous type in which the cartilage of the joint has entirely disappeared, represent the largest groups of cases in which mobilization may be considered. There is also another type which may enter the realm of mobilization—the joint fixed in a fibrous union that is not firm. A limb had better be "rock-stiff" than have an arc of motion that is not serviceable. The functional arc of motion varies in the different joints. A knee to be useful must have at least 25 to 30 degrees of movement. The arc of motion required by the elbow is even greater. In the hip-joint no less than 20 to 25 degrees of motion is of value. A wrist with motion of less than 5 to 10 degrees is open to strain.

The presence of limited movement in a joint is of no use to the patient; it only causes the joint to be strained and wrenched more easily, with a consequent breaking up of the adhesions already formed. Such a joint is extremely painful. Consider, for instance, a case of ankylosis of the knee. Provided the limb is firmly fixed in proper functional position, the patient can walk, run, and even dance without suffering any symptoms. But suppose that the knee has 5 to 8 degrees motion, the patient then cannot move his limb to any extent without straining the joint, which causes a recurrence of the acute process, or a breaking up of the adhesions if the active infection has already quieted down. Swelling and effusion occur. The patient suffers from an acute joint, and he begins to lack confidence in the capacity of the joint to do its normal work. Mobilization is indicated in these cases in which the motion present is not sufficient for ordinary use.

It is difficult to determine which variety of ankylosis lends itself more satisfactorily to arthroplastic procedures. Mobilization in either the bony or fibrous type is technically easier if the joint still retains the old articular line, which one can follow in breaking down the ankylosis. In complete bony fixation, in which there is entire obliteration of the joint surfaces, one must decide where the line of cleavage should come, and one must do considerable hammering and

remodeling. A procedure so extensive is accompanied by a great deal of postoperative reaction. In spite of these difficulties, in our experience we have found that this bony variety is the better type to mobilize. To perform operations upon these cases is like working with a hard piece of wood. In the fibrous type, on the other hand, extensive atrophy is often present, and there is always the possibility of the persistence of a low-grade infection.

Many operators find the fibrous ankylosis easier to deal with than the bony variety because of the difficulty of remodeling. Some operators believe that they have failed to obtain satisfactory results in bony ankylosis because the capsular and ligamentous structures had been removed. Surgeons who are experiencing this difficulty are not performing a true arthroplasty, which entails the preservation of the supporting structures. Still other operators claim that the chances of success in the bony variety are not so favorable because of the difficulty in building up the muscular control following operation. This trouble may be obviated somewhat by strengthening muscles before mobilization by voluntary contractions.

Condition of Bone, Musculature, and Skin.—Bone atrophy or osteoporosis makes operation difficult, especially as to remodeling and fitting the component parts. One often sees an elbow in which there is such extreme atrophy that the medullary cavity is almost completely filled with oil and the medullary tissue is only a fine network, due to the extensive calcium absorption. In some cases, the atrophy and osteoporosis may contraindicate arthroplasty until normal bone has been restored.

The condition of the important muscles that control the joint must be checked very carefully. The flexors and extensors of the joint must be free from infectious and traumatic scarring. Occasionally one sees the muscles and tendons bound down when sepsis has involved these structures as well as the joint. The presence of extensive scar tissue hinders the routine technique of the operation, because so much of the soft tissue which contain bloodvessels has been destroyed. The ultimate outcome in these cases is questionable, especially if there is any infection or if any pressure-slough occurs.

Atrophy of the muscles has an important bearing upon convalescence. It is impossible to begin normal activity early, an important step in the after-treatment of operation, if extreme muscular

atrophy exists. The degree of atrophy depends upon the duration of the period of disuse; more atrophy will be found in a limb that has been ankylosed for fifteen years than in a limb that has been stiff for only one year. The musculature of the leg in particular atrophies quickly when the limb is not used. This is noticed especially in the atrophy of the quadriceps when the knee is ankylosed in flexion. Here again is another plea for the treatment of joints in proper functional position. In long-standing cases, atrophy should be treated before operation by massage and by practising voluntary contraction of the muscles.

The condition of the skin is another factor to be considered. If the skin is tight and adherent to the bone, it should be treated before arthroplasty is done. The presence of fat and subcutaneous tissue is necessary to the success of the operation. If both these tissues are lacking entirely, or if it is found impossible to excise the adherent area of skin, a difficult operation is to be expected, and in most instances arthroplasty is contraindicated.

The Position of the Ankylosed Member.—If the surgeon is dealing with a limb stiff in malposition, he must consider the relation of deformity to the loss of motion. Supposing the deformity were corrected, would the increase in motion be sufficient to make the limb useful? Deformity always causes a loss of motion, and its presence may be the principal source of disability.

Age.—The preferable age at which to perform an arthroplasty is between twenty and forty years. It is usually a patient about forty years of age, who is seriously striving to recover motion. No attempt should be made to mobilize a joint until epiphyseal growth has ceased, for it is impossible to remove sufficient bone to secure motion without grave danger of injury to the epiphyseal line.

Occasionally operation may be performed when the patient is more than forty years of age, but as a rule, an older person should not be subjected to extensive joint surgery. In two exceptional cases, we have performed arthroplasties on persons who were more than forty years of age. Our first patient with an ankylosed knee was aged sixty-three years. The ankylosis was bilateral. The patient had a general arthritis and was a poor risk. Contrary to expectation, she obtained excellent motion after operation. In fact, she was so pleased with the result that she requested mobilization of the other knee, but we refused because of her arthritic condi-

tion, which naturally had interfered with her muscular development and would affect her endurance in convalescence. Not long ago, we performed another arthroplasty on an ankylosed knee in a patient aged about fifty years. As he owned a ranch it was imperative that he should be able to ride horseback. His health was excellent at the time of operation. The result was splendid. (See Case X.)

General Condition of the Patient.—The patient must be in excellent condition. There should be a careful routine checking of all possible sources of infection. The importance of the eradication of infectious foci may be illustrated from failures in our own practice, which were due to lack of observance of this step before performing the arthroplasty. At least three of our cases failed because of the lighting up of foci in other parts of the body. The first of these cases, a boy with an ankylosed knee, had an excellent operative result for a period of a month or six weeks. Then sepsis developed in his jaw, due undoubtedly to an abscessed tooth. The result was that the knee wound suppurated, and a phlegmonous infection developed, which was purely secondary to the jaw infection. The second case, one of an ankylosed elbow, developed an acute fulminating abscess of the appendix two weeks after arthroplasty. From the time of operation the elbow-joint had been perfectly clean, but it then went septic and had to be opened and Dakinized. Upon the removal of the appendix, the elbow wound healed quickly, and the patient obtained splendid motion.

The third case was that of an ankylosed knee in which the prognosis was most promising. On the ninth day following arthroplasty, intestinal symptoms developed, which puzzled four medical men. In the course of a week, the patient had a tense, swollen abdomen, and was practically moribund. We advised immediate operation, realizing the seriousness of the condition, and believing that the patient should at least have the advantage of a laparotomy. Upon opening the abdomen, free gas and fluid were found, signifying, of course, a perforation. This perforation was not found at the time of operation, and the patient was in no condition to warrant further exploration. Wicks were inserted. At the time when the abdominal symptoms appeared, there was evidence of sepsis in the knee-joint. The wound was opened, and the joint Dakinized. The patient recovered and obtained a good functional knee. (See Case X.)

Circumstances of the Patient. – Although, in general, definite indications for operation must rest upon the judgment of the surgeon, the decision to mobilize will be influenced to some extent by the occupational and social status of the patient. A stiff limb that is a great handicap to one patient may be of only slight inconvenience to another. The after-treatment in every case is long and painful, requiring the coöperation of the patient to the fullest extent. It is well to discuss these aspects of the case very carefully before proceeding.

General Discussion of Contraindications.—There have been several contraindications to arthroplasty expressed from time to time by various operators, which we have not mentioned above. A few surgeons believe that the chances of success are lessened in cases in which the destruction extends beyond the joint surfaces into the shaft of the bone. For example, they would not advise mobilization if, in addition to solid union of the joint surfaces of the tibia and femur, the two bones formed one shaft. In our opinion, arthroplasty is not contraindicated in such a case, provided the musculature is suitable for operation, and provided there is not excessive scar tissue or discharging sinuses. If disease or sepsis has destroyed the ligamentous structures about the joint, one must be cautious in interfering, particularly in a weight-bearing joint, but if one finds that there is ligamentous stability about the joint, with muscle control, it is possible to do an arthroplasty. The shaft being firm, an extensive operation must be expected. The advisability of arthroplasty would depend primarily, of course, upon the ultimate worth of motion to the patient.

The presence of eburnated bone for a few inches on either side of the joint-line, although not a definite contraindication to arthroplasty, lessens the chances of success. The etiology in such cases is usually an extensive osteomyelitic process that gives rise to an unhealthy bone condition. In a rare case, a favorable outcome may be obtained provided the capsule and muscles are strong enough to support a joint with motion.

Shortening, if extreme, is a contraindication to arthroplasty. Slight shortening may be easily compensated after operation by a lift on the shoe.

THE RESULTS OF ARTHROPLASTY.

Arthroplasty cannot, of course, restore the joint to normal, but in many cases it creates an articulation that is as satisfactory from the point of view of service and function as is the normal joint. The new joint has stability; it is strong; it adapts itself well to weight-bearing; and its nicety of motion makes the limb a functional and serviceable member. Furthermore, there is a psychic assurance of the usefulness of the joint.

The Function of the New Joint.—The results of mobilization cannot be estimated for all joints collectively. Each joint presents its own problem. Roughly, we may say that the new joint will have smooth motion, usually to within 75 to 90 per cent of normal. In some cases, more limited motion may result, but the joint will be a serviceable one provided the limb is stable. In our early cases we were most anxious to secure a full range of motion, but we now realize that it is more important to secure stability, since a stable limb even with limited motion is a satisfactory member. We mobilized one case of elbow ankylosis, due to a septic fracture, that had scars and burns all the way up the arm. It was a difficult case surgically, and there was some question as to whether mobilization was indicated. There was no fat between the skin and olecranon, and the skin was red and tense. We decided to perform an operation, which resulted in a stable arm with good function, even though there was some limitation of extension. The patient is now driving a truck and changes the tires himself.

The time required for the recovery of motion following arthroplasty depends upon several factors, most important of which is the type of joint that has been treated. The recovery of motion in the hip and knee is slower than in other joints, because the functional capacity of the gluteal muscles and of the quadriceps returns slowly. The period of convalescence is shortened by carrying out in detail and with extreme care all the principles of after-treatment. Never at any time should the joint be forced in an attempt to gain motion.

The condition of the musculature influences the time required for the recovery of motion. In a joint ankylosed for a number of years, as for instance, fifteen years, a great deal of atrophy has taken place, and the return of voluntary motion naturally must be slow.

Atrophy from disuse seems to occur more extensively in knee-joint lesions than in other joint conditions. Painstaking treatment by passive and active exercise and by massage is required to restore the tone of the muscles to the point where they can function sufficiently to control the joint.

The coöperation of the patient in trying to secure motion influences the rapidity with which function is regained. If the patient is one who fears pain and constantly holds the joint rigid to avoid it, attempt at movement is impossible. To eliminate this difficulty we have used mechanical devices which the patient himself can regulate in producing motion. A person who ordinarily will not stand being hurt by the operator gains confidence when he can guide the motion himself.

The causative agent of the ankylosis has some bearing upon the return of function. For example, if the origin of the stiffness has been arthritis, the joint does not become truly functional for a period of at least six months. Motion then increases slowly and steadily for three or four years.

Once motion is regained, there is little danger of losing it. Our statistics show that good motion has been retained in cases for more than ten years, with the joint being subjected to heavy work. We have ample proof that the new joint will be able to endure for a period of many years. We also find that, with use, the arc of motion increases.

Anatomic-morphological Changes in the New Joint.—Secondary operations in joints for the removal of spurs, and surgical interference in elbow cases for the removal of the head of the radius, have given operators the opportunity to examine the recovered joint. The bone-ends are smooth and covered with a firm fibrous tissue. They fit snugly, yet move with a minimum of resistance. The joint-space is a sac, sometimes multilocular, and contains an apparently normal joint-fluid.

Roentgen films also demonstrate the excellent structure of the newly-formed joint. An articular space is sharply defined. If the arthroplasty has been performed properly there are no spicules of bone and no loose bodies. Some operators believe that the joint always has the appearance of an osteoarthritic joint. If signs of an osteophytic process are present, they are largely the result of faulty technique, particularly due to the operator's neglect to round the

corners of the bones carefully. Too many arthroplasties have been carried out like excisions, in which a mass of tissue and bone is removed without any remodeling.

WHAT BECOMES OF THE FASCIA?

One naturally is interested in what becomes of the flap of fascia which is interposed into the joint. Several theories have been advanced, but so far, there has been little experimental work upon which to base an opinion. There is also some question as to how much value experimental results would have, since it has not been found possible to produce in animals the same condition that is found in ankylosed human joints. That the flap remains viable after transplantation has been proved by Kirschner,[63] König,[64] Kostenko and Rubaschew,[46] and Kornew.[65]

The theory most often advanced as to the changes that take place in the fascia, and one that seems most consistent with the renewed function of the joint, is that the flap heals and undergoes transformation either into connective tissue or into some sort of hygromatous tissue. Putti[66] found that the fascial flap, three years after operation, had transformed into connective tissue with a new cartilaginous formation. Beye and Steindler,[67] in experimenting on dogs with the interposition of muscle and fascia, found that after merely scraping the cartilage and interposing the flap, the muscle and fascia were transformed into a connective-tissue pannus, which became adherent to the denuded areas of the bones. This transformation into connective tissue was complete, and there were no traces of the original fibers of the flap.

The writers support the theory that the flap is transformed into a connective tissue which acts as a covering for one of the articular surfaces. This covering is not unlike that seen in a case of nonunion. Under the influence of motion, a fluid is secreted which keeps the opposing surfaces well lubricated.

Other theories on the transformation of the fascia have been expounded by Bastinelli[68] and by Kirschner.[69] Bastinelli believes that the flap itself does not affect the mobilization, but that it regulates the proliferation of tissue. It forms a frame along which new tissue grows. The superficial layer disappears quickly, and the

deep layer, which is in contact with the bone, heals totally or in part, but is finally replaced by new growth.

It is Kirschner's opinion that the flap must disappear entirely, or otherwise it would hinder mobilization through adhesion. He believes that the flap has a tendency to form fibrous tissue and adhere to the articular surfaces, with the result that the formation of cicatricial tissue prevents movement. Putti,[70] however, arrived at opposite conclusions. In his experiments on dogs, he found that the fascia not only prevented the formation of adhesions, but that it checked the osteogenic power of the extremities. The fascia kept its histological properties except on the edges where there were some areas of necrosis.

EXPERIMENTAL WORK.

Arthroplastic mobilizations of the joints of animals have been few, and as we have stated above, it has not been possible to produce in animals conditions similar to those in human joints. Experimentally, the end-results of arthroplasty and those of excision have been the same (Allison and Brooks,[71] Hohmeier and Magnus,[72] Phemister and Miller[73]).

Neff[74] reported only 1 successful case out of 4 arthroplasties on dogs in which free transplants from the rectus aponeurosis were used. Three cases were ruined by infection. The successful operation, in the case of a knee-joint, showed that new capsule had formed, and that there was connective tissue between the tibia and the femur as well as the development of two bursal sacs.

Kolazek,[75] in 5 experiments on dogs, excised a portion of the capsule and inserted homotransplants of peritoneum. The flaps healed and formed no adhesions.

Sumita[76] destroyed the joint surfaces of the knee, hip, and ankle of 20 dogs and interposed pedicled flaps. The dogs were observed for periods of twenty-one to two hundred and forty-four days. Fibrous tissue and small cavities formed, but the largest cavity measured only 1.5 cm. in diameter.

Davis,[57] in his experiment on the knee-joint of a dog, found at autopsy that the free fascial flap was adherent to the end of the femur, and that the flap was viable.

Segale,[77] in 1913, in a series of experiments on rabbits and dogs, found that the joint capsule had reproduced itself from the sur-

rounding tissue, and the new capsule limited the joint cavity and contained synovia. The reproduction of the joint surroundings was closely connected with the operative technique, which provided for the preservation of those parts that assured a correct joint mechanism.

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PART III.

ARTHROPLASTY OF SPECIFIC JOINTS.

ARTHROPLASTY OF THE ELBOW-JOINT.

An ankylosed elbow is more objectionable than a stiff joint in any other part of the body. Whereas most joints can be placed in a position in which, even though ankylosed, they can function to a certain extent, there is no position in which a stiff elbow allows satisfactory function. The position of choice in ankylosis of this joint, when only one extremity is involved, is about 90 degrees flexion. If both elbows are likely to become ankylosed as the result of a pathological process, one is placed in flexion and the other in 110 to 120 degrees extension. But ankylosis even in these favorable attitudes handicaps the patient, for the movement of the arm is never satisfactory, and the limb is in an awkward position.

It is seldom that one sees an elbow ankylosed in acute flexion, and this is unfortunate, for although the position offers no advantage as far as motion is concerned, still it is preferable to one of deformity. In a series of over 100 ankylosed elbows that we have mobilized, not one was stiff in the position of acute flexion. Extension at about 160 degrees is the position in which ankylosis usually takes place, because lesions of the elbow, whether of infectious or traumatic origin, are generally treated with the arm in extension. While the member is not unsightly in the extended attitude, still it is awkward and practically useless. It is to be noted that many elbow-joints probably would not have become stiff had the initial lesion been treated in the position of acute flexion.

In view of the great inconvenience of a stiff elbow, it is fortunate that this joint lends itself well to mobilizing procedures. Provided the etiological process has been quiescent for at least one and a half years, and provided the age of the patient, his general health, and the condition of the skin, musculature, and bone from a local aspect, are favorable to arthroplasty, mobilization is always indicated. Our experience in arthroplasty of the elbow-joint has been extensive, and

we have mobilized from 90 to 100 ankylosed elbows with remarkable success. In the majority of cases, the joints have had an excellent range of motion, they have been stable and painless, and they have withstood a certain amount of heavy work without showing any arthritic changes. Some of our early arthroplasties resulted in limited, but perfectly serviceable motion. In the entire series there were only three failures, and these occurred in our first group of cases. One patient was a young child and we should not have attempted operation. Two cases became septic.

An arthroplasty of the elbow-joint to be judged successful must not only restore motion to the joint, but it must establish stability. Some of our early mobilizations resulted in complete motion in flexion and extension. In fact, a little hyperextension was sometimes possible. As we gained experience, however, we realized that stability and firmness were of more value to the patient than a complete arc of motion. A person who performs household tasks may find an elbow with a full range of motion perfectly satisfactory, but a man who has to use a hammer requires stability with motion. Limited motion with stability is preferable to an unstable joint with a full range of motion. An elbow that allows flexion to 45 degrees and extension to 170 degrees is the most serviceable joint.

Operative Technique (Writers'). —The arm from the wrist to the shoulder, and the leg from the hip to below the knee on the same side of the body, are given a two-day preparation. At the time of operation an Esmarch tourniquet is applied to the upper third of the arm, and an application of iodine is made to the skin from the finger tips to the upper arm. The tourniquet should be applied firmly enough to control hemorrhage, but in order to avoid tourniquet paralysis, care should be taken not to apply it too tightly.

The incision is semicircular, beginning over the external condyle, curving over the olecranon, and extending over the internal condyle. (Fig. 3.) The wound is wiped with an alcohol sponge, and the skin is clamped off carefully to avoid handling during the operation. The flap containing the skin and superficial fascia is dissected back to its base-line and retracted. The ulnar nerve is isolated and removed from its bed with a blunt dissector. (Fig. 4.) Care must be taken not to break or injure it. After the nerve has been freed up and down for 3 inches, a small ribbon of gauze, which has been wet in salt solution, is passed beneath the nerve, and it is retracted to the

ulnar side over the inner condyle. In old comminuted fractures it may be difficult to locate the nerve, but it is usually found beneath the fascia between the internal condyle and the olecranon.

FIG. 3.—Elbow arthroplasty. Line of incision. (MacAusland.)

A transverse incision running from condyle to condyle is made through the fascia and muscle attachments down to the joint. (Fig. 5.) The olecranon is divided transversely about 1 inch from its tip.

(Fig. 6.) The flap outlined by this incision is dissected back and preserved *in toto* for a subsequent covering for the joint. At first, the dissection of this flap will be found difficult and tedious, particularly on the inner side where the fascial covering is thin and might easily be buttonholed. After the flap has been pulled back a short distance, further dissection may be easily carried out by gauze

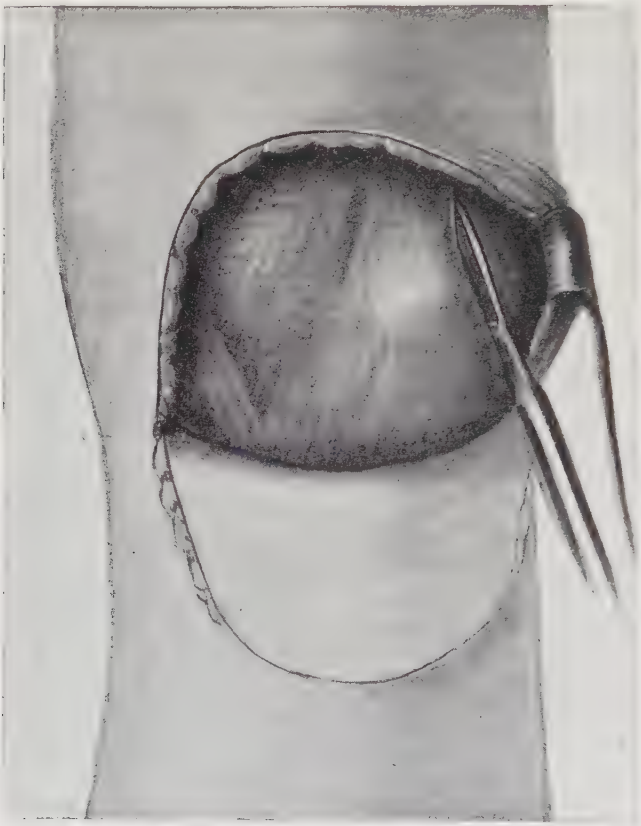

Fig. 4.—Elbow arthroplasty. Dissecting out ulnar nerve. (MacAusland.)

pressure. In some cases it is now possible to break open the old joint; in other cases in which the joint-line has been sufficiently preserved, it is possible to separate the articular surfaces with a curved chisel; and in still other cases, in which the ankylosis is osseous and the joint-cavity obliterated, it is necessary to saw through the joint.

In some cases, the tip of the olecranon may have to be chiseled out of the humerus and dissected back with this posterior flap. Usually the olecranon tip is large and it is well to reduce its size a little at this time. (Figs. 7 and 8.) A small portion of the lower end of the humerus is nipped off with a rongeur forceps, and a new trochlear or intercondylar surface is formed. A shoemaker's rasp is used in

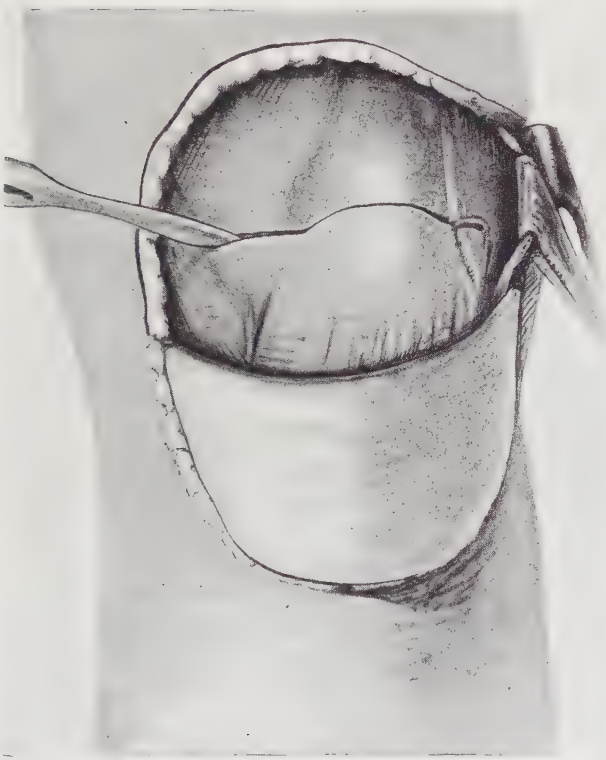

FIG. 5.—Elbow arthroplasty. Cutting through the fascia and muscle attachments down to the joint. (MacAusland.)

filing the humeral end to simulate the normal articulation. The olecranon fossa is enlarged slightly toward the joint surface to receive the olecranon. The modeling is done largely with a rasp and file. One must be careful in making this cup, as the success of the operation depends a great deal upon attention to such small details. To ensure good function and stability, the joint surfaces must fit

accurately. Only sufficient bone is removed to allow a free arc of motion; if too much bone is removed, a flail joint will result. The ulna surface is scooped out with a curette or rasp. (Fig. 9.) The

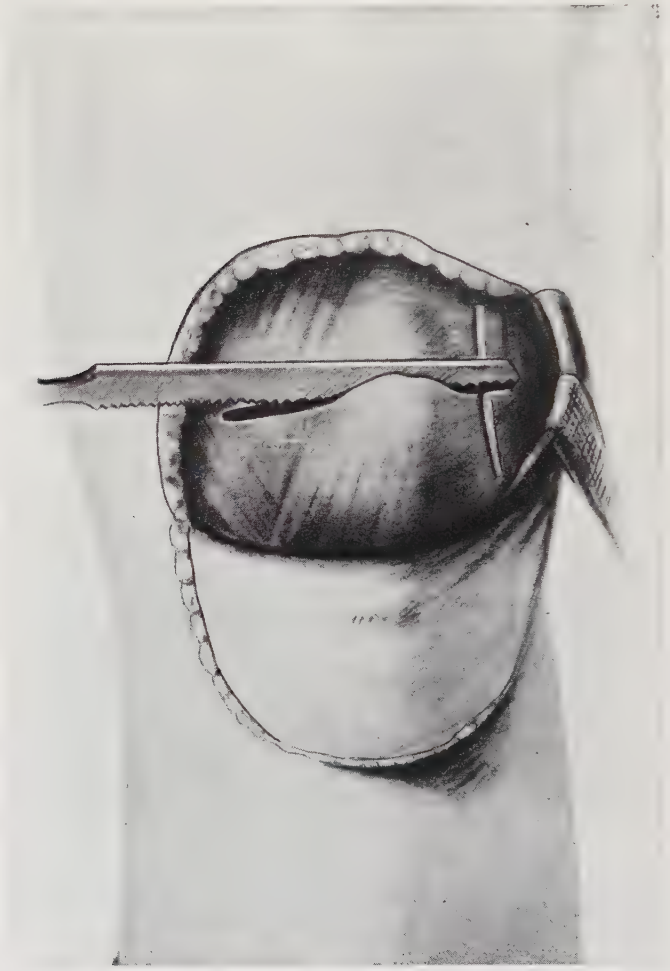

FIG. 6.—Elbow arthroplasty. Sawing through olecranon and end of humerus when necessary. (MacAusland.)

treatment of the radial head is problematical. The writers believe that it should seldom be disturbed as it is of value in forming the base for the external condyle in the new joint. Occasionally we have placed a piece of fascia between the radius and ulna, but only in cases

in which such a procedure is simple. This step might well be reserved for a secondary operation, which, however, few cases seem to require since arthroplasty affords a range of motion in flexion and extension sufficient for ordinary use without movements of rotation.

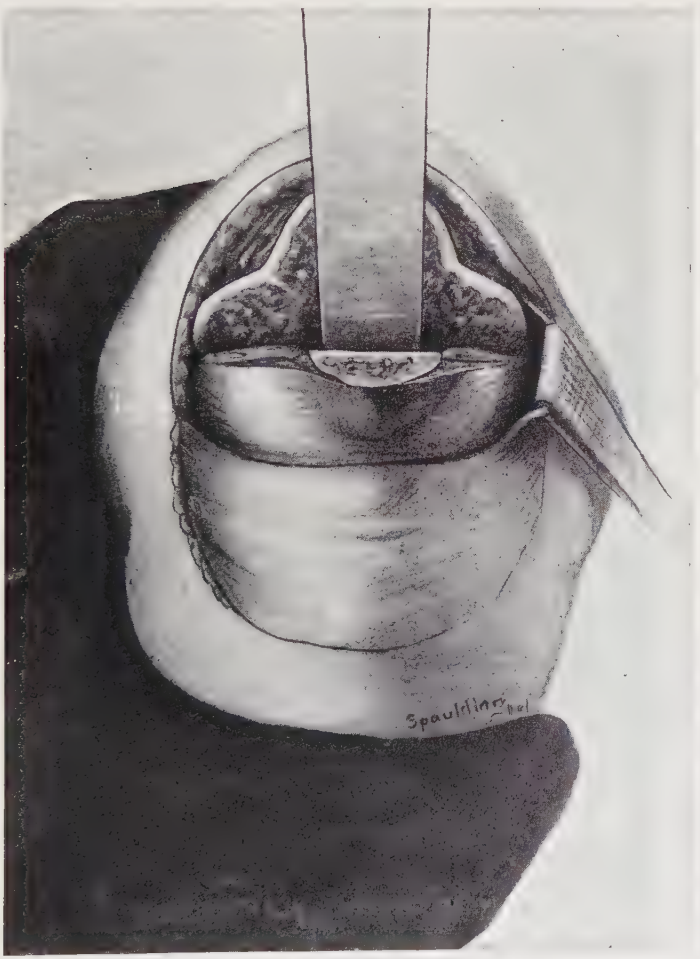

FIG. 7.—Elbow arthroplasty. Freeing tip of olecranon. (MacAusland.)

A flap of fascia is then secured from the thigh. (Fig. 10.) An incision extending down to the fascia lata is made on the outer and lower side of the thigh, slightly below the middle. A flap of fascia

5 to 7 inches in length by 4 to 5 inches in width, and free from fat, is dissected out. The wound is closed.

The fascia is first wrapped around the newly-formed humeral condyles and fixed securely in place by winding chromic catgut around the shaft of the humerus just below the condyles. The remaining part of the flap is brought over the cavity in the ulna and

Fig. 8.—Elbow arthroplasty. Cutting out with ronguer forceps bit of olecranon tip left attached in humerus. (MacAusland.)

then folded back up the humeral shaft as far as the olecranon fossa. The fascia is attached anteriorly to the old capsule, and posteriorly to the periosteum and deep fascia over the humerus, with interrupted chromic catgut sutures No. 2. In this way, a double layer of fascia is inserted into the joint, which we believe adds to the stability, since it allows the joint to be closed tightly. This step is a new

development in our technique, as previously we have used only one layer of fascia in the joint. (Figs. 11 and 12.)

The radius and ulna are placed in apposition with the condyles. Two drill-holes are made, one in the olecranon, and one in the shaft of the ulna. Chromic gut No. 2 is passed through these holes and tied to hold the olecranon in close apposition with the ulna. (Fig.

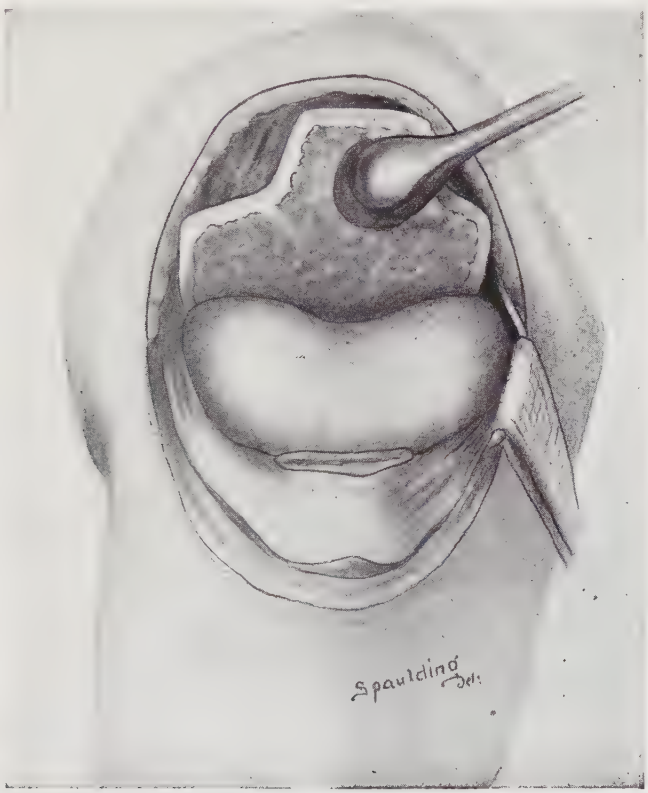

FIG. 9.—Elbow arthroplasty. Scooping out ulna with curette. (MacAusland.)

13.) The old capsule and fascia are sutured with chromic catgut No. 2. (Fig. 14.) The wound is closed, and dry sterile dressings are applied. The arm is placed in a plaster bandage in as much flexion as the sutures can stand. Usually we allow the arm to drop into flexion by its own weight, and we fix it in this flexed position.

If we are mobilizing an elbow that has been ankylosed in extension, with a consequent contraction of the posterior tissue, we remove a

little more bone than in an ankylosis at a right angle or in flexion, and we keep the arm in flexion a little longer during convalescence.

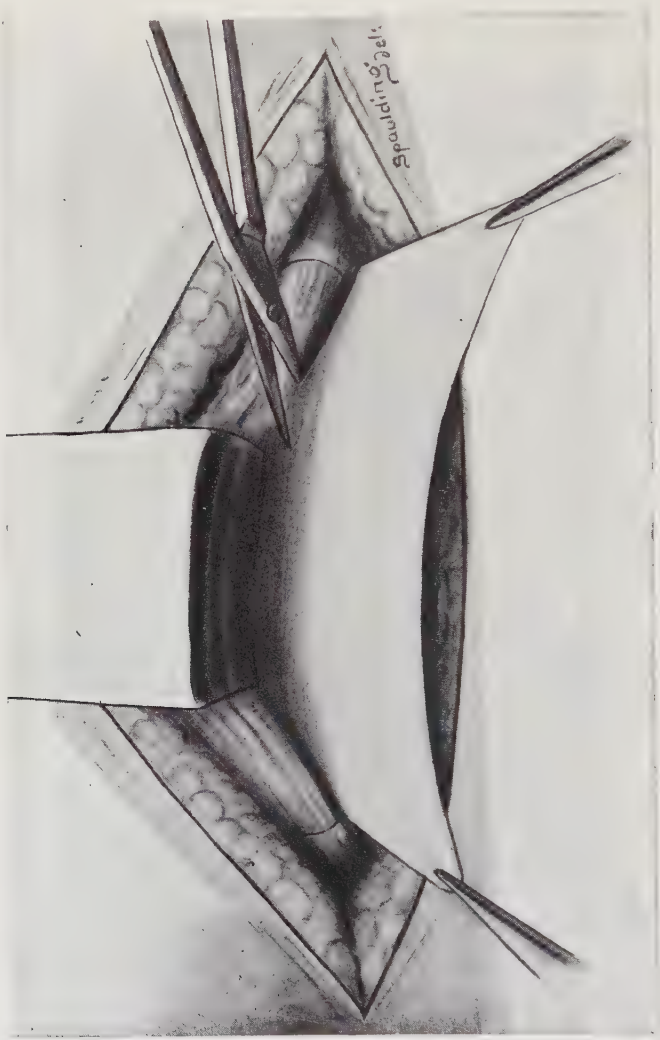

FIG. 10.—Elbow arthroplasty. Removal of fascia lata from thigh. (MacAusland.)

After-treatment.—The after-care forms a vital part of the arthroplasty. The patient must be under observation for a long time. Roentgen films should be taken so that one may follow the changes in the joint.

The plaster bandage remains on for a week. It is then split and

the dressing changed. In case of a persistent temperature, a window is cut in the plaster, and the wound inspected. Passive motions are begun in about ten days, when the pain has subsided and the tenderness has disappeared. By the use of the traction apparatus of White,[1] of which the Jones humerus extension splint forms the

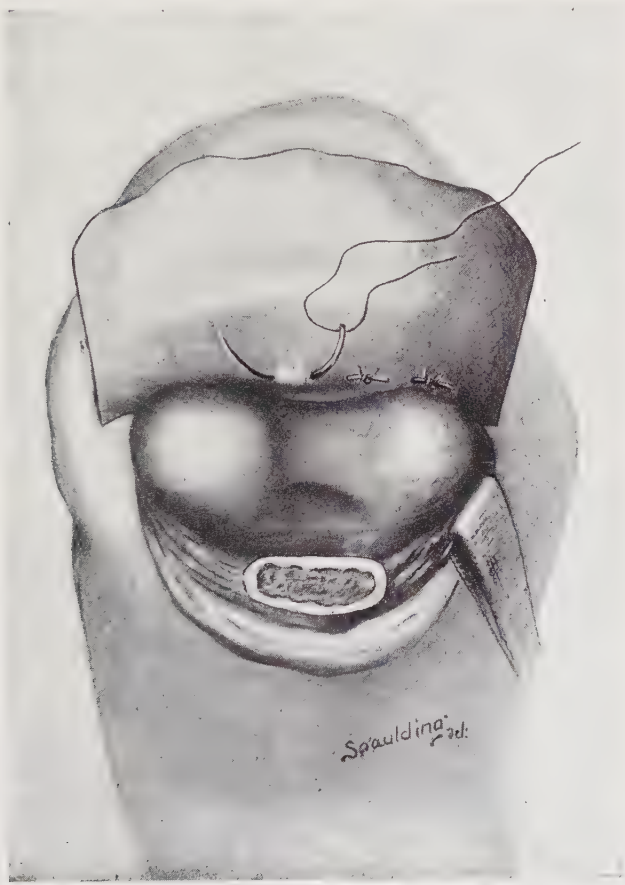

FIG. 11.—Elbow arthroplasty. Sewing flap of fascia lata to anterior capsule. (See text for new technique.) (MacAusland.)

basis, the patient may guide these movements himself. The motion should never be forced or attempted in the presence of pain. In three weeks, the joint is given baking and gentle massage three or four times a week. In six weeks, the patient is encouraged to flex and extend his arm voluntarily. If motion begins to shut

down, the arm should be manipulated under an anesthetic, and the elbow placed in acute flexion. Should motion become limited as the result of an exuberant growth of new bone, a sequela that is seen occasionally, a secondary operation is performed to remove the new

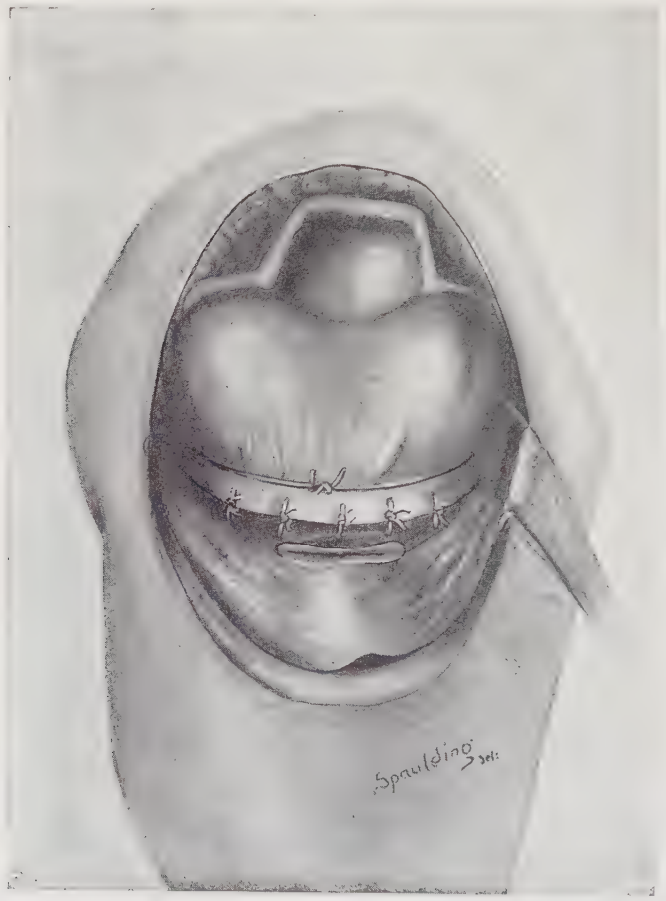

FIG. 12.—Elbow arthroplasty. Fascia sewed over humerus, tied with chromic catgut suture. (See text for new technique.) (MacAusland.)

bone. Such a procedure should not be undertaken for three or four months after the original operation.

CASE II.—W. D., aged forty-two years. This was our first elbow arthroplasty, to which we referred in the chapter on Arthroplasty in General.

History.—The patient received a contused wound of the left thumb, which became septic. One week later sepsis became general. Five incisions were made in the left hand, two in the left wrist (one of which was close to the elbow-joint) and one in the left hip. Drains were inserted in all the openings. A student opened a swelling near the right elbow and cut into the joint.

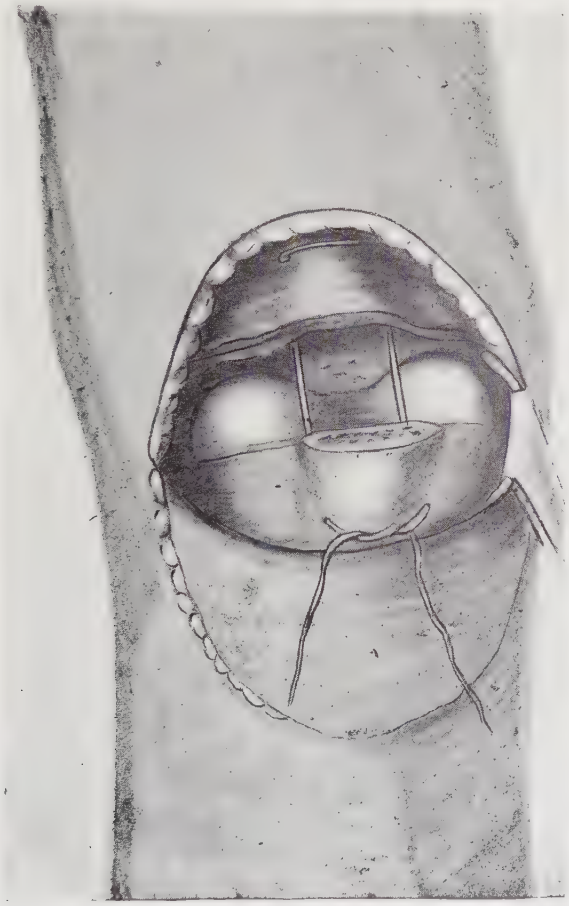

FIG. 13.—Elbow arthroplasty. Chromic gut suture through ulna and olecranon tip. (In new technique only two drill-holes are made.) (MacAusland.)

At the end of twenty-one weeks the patient was discharged from the hospital with bony ankylosis of the right elbow and with only a few degrees of motion in the left elbow. Both joints were

extended. The patient could not touch his head with either hand or feed himself.

Treatment. - March, 1912: An arthroplasty was performed upon the right elbow.

Fig. 14.—Elbow arthroplasty. Stay sutures. (MacAusland.)

Six weeks after operation it was found that the patient could not use either the biceps or the triceps, because of atrophy due to the long period of disuse. By careful training of the muscles, he finally was able to flex the forearm voluntarily. Improvement gradually took place.

Result.—A stable, useful elbow with a good range of motion was obtained. (Fig. 15.)

Case III.—W. D., aged forty-two years.
History.—The history of this case is reported under Case II.

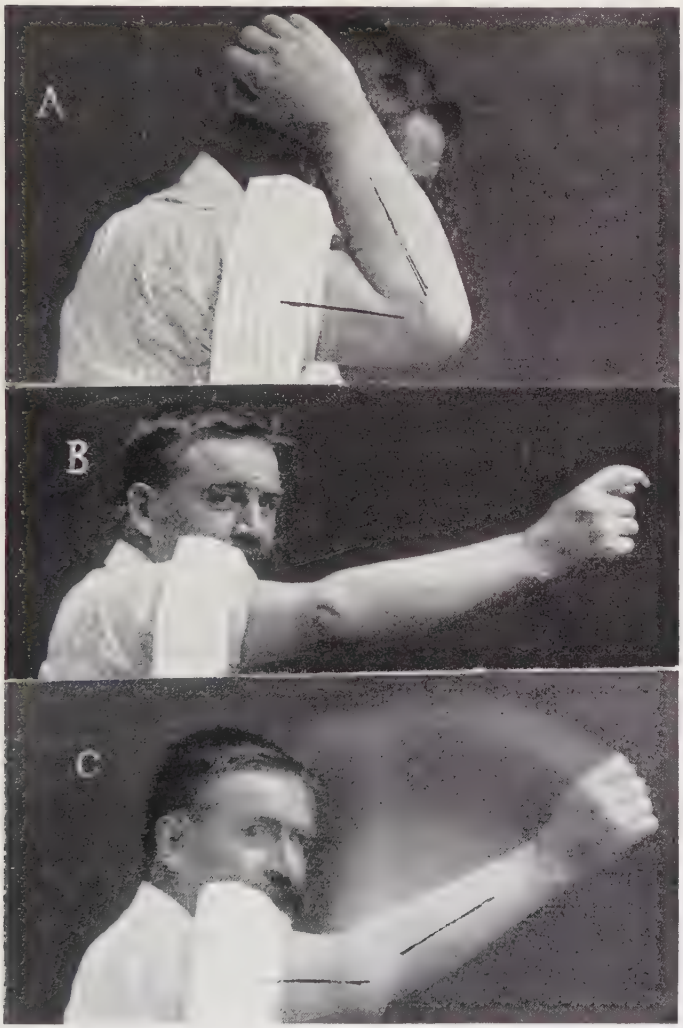

Fig. 15.—Case II. W. D. Showing voluntary flexion, extension, and range of motion, six months after arthroplasty. (MacAusland.)

After arthroplasty of the right elbow the patient requested that a similar operation should be done on the other joint. A Roentgen film showed the elbow ankylosed at 90 degrees. (Fig. 16.)

Treatment. January, 1914: An arthroplasty was performed upon the left elbow.

Result.—The end-result was excellent, and the elbow was stable and had motion from 60 to 160 degrees.

When the patient was last heard from, ten years after the second arthroplasty, he was working as a lumber-jack.

FIG. 16.—Case III. W. D. Roentgen film showing bony ankylosis before arthroplasty. (MacAusland.)

CASE IV.—H. F., aged thirty-five years.

History.—This patient presented a positive history of gonorrheal infection. Fifteen months previous to her admission to the hospital pain started in the right foot, in the left arm, and in the fingers of both hands. She was in bed three months, and during that time the pain in the right elbow was severe. The elbow gradually became stiff.

Physical Examination.—When the patient came to our clinic the elbow-joint had been stiff for fifteen months. Ankylosis, bony in character, had taken place at about 110 degrees extension. (Fig. 17.) Supination was about one-quarter normal, and pronation was one-fifth normal. The wrist was normal and she could make a weak fist.

Treatment.—November 9, 1923: An arthroplasty was performed,

Result.—June 24, 1924: The elbow was stable. The patient had complete extension and flexion. (Figs. 18, 19 and 20.) This

Fig. 17.—Case IV. H. F. Roentgen film showing bony ankylosis in position of 110 degrees extension before arthroplasty. (MacAusland.)

Fig. 18.—Case IV. H. F. Showing complete flexion, eight months after arthroplasty. (MacAusland.)

function has been retained until the present time (October, 1928), and the patient has a perfect result.

FIG. 19.—Case IV. H. F. Showing complete extension, eight months after arthroplasty. (MacAusland.)

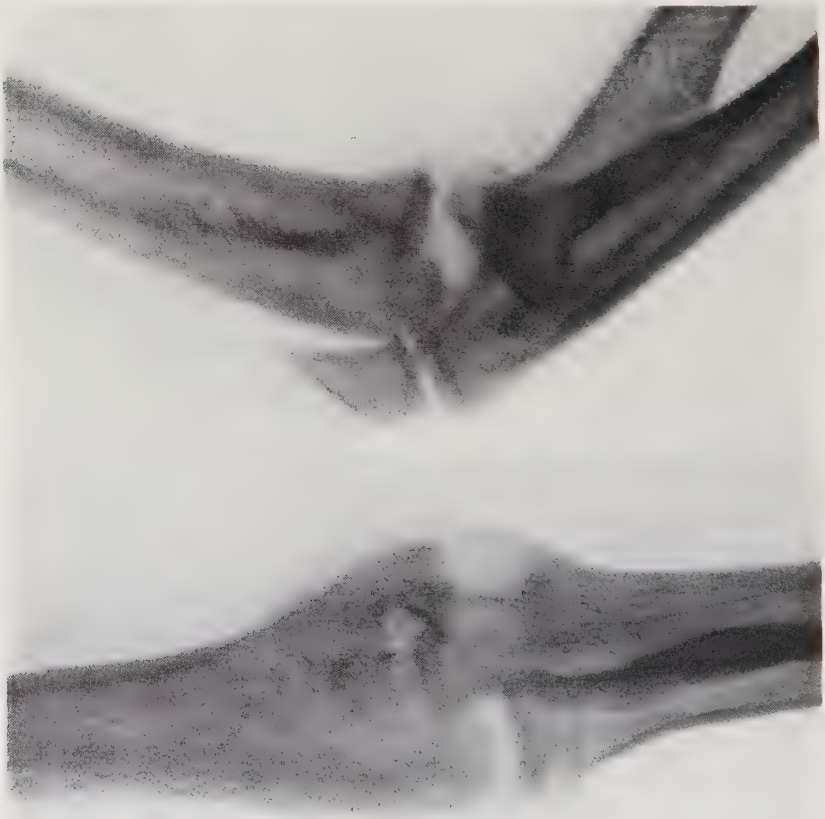

FIG. 20.—Case IV. H. F. Roentgen films showing joint space after arthroplasty. (MacAusland.)

Case V.—I. H., aged thirty years.

History.—This patient fractured her right elbow. Following reduction she suffered considerable pain and was unable to use her arm. Four months after the injury we manipulated the elbow under ether, and later other manipulations were carried out. The limitation of motion was not overcome.

Fig. 21.—Case V. I. H. Antero-posterior Roentgen film showing joint-space following arthroplasty. (MacAusland.)

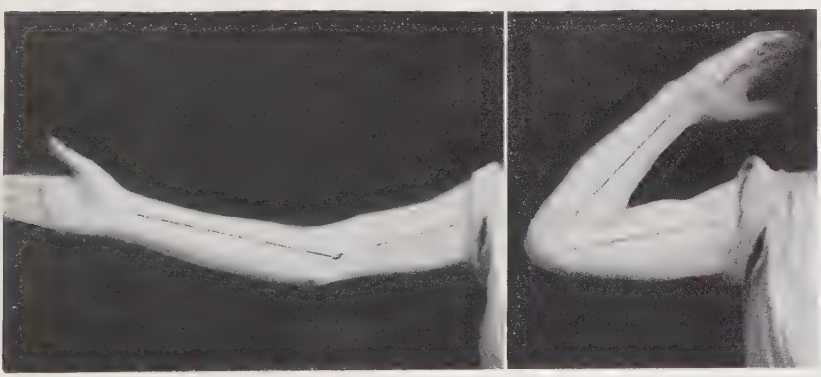

Fig. 22.—Case V. I. H. Showing range of motion three years after arthroplasty. (MacAusland.)

Physical Examination.—June 22, 1915: Motion in the elbow was limited to 40 degrees. There was no pain, but the joint was somewhat tender and enlarged, and grated on movement. A Roentgen film showed an old fracture through the end of the humerus.

Treatment.—June 23, 1915: An arthroplasty was performed. The following day the plaster was trimmed about the fingers.

Swelling and fever continued for several days until, finally, on June 28, 1915, the plaster bandage was bivalved. The temperature then dropped and the edema disappeared.

July 6, 1915: The dressing showed slight superficial sepsis. The motion of the arm was very much increased.

Result.—The motion continued to increase gradually, until *June, 1919,* three years after operation, the elbow had a range of movement from 37 to 125 degrees. (Figs. 21 and 22.) The motion continued to increase, and when the patient was seen in *November, 1923,* function was about normal. Flexion and rotations were normal, and extension was possible to within 15 degrees of normal. There was considerable enlargement of both condyles and some loss of the carrying angle. The patient had no symptoms and was doing nursing and household work without difficulty.

FIG. 23.—Case VI. L. P. Voluntary flexion and extension after arthroplasty. (MacAusland.)

CASE VI.—L. P., aged twenty years.

History.—In 1912 this patient was confined in bed with an infectious arthritis involving the feet and wrists. In spite of orthopedic care the trouble progressed.

Physical Examination.—July 10, 1914: There was marked involvement of all joints of the arms and legs, with more or less pain, swelling, and stiffness. The left wrist was ankylosed at 35 degrees radial adduction and the left shoulder showed a bursitis. The left elbow was ankylosed at about 135 degrees extension and had only a few degrees of motion.

Treatment.—The shoulder, hips, knees, and ankles were manipulated under ether.

January 13, 1915, an arthroplasty was performed on the left elbow. The olecranon was found to be ankylosed to the humerus, and both the humerus and the ulna showed a large amount of bone atrophy.

October 13, 1915: The deformity of the wrist was corrected.

February 6, 1916: An excision of the shoulder was done.

Result.—July 23, 1919: Four and a half years after arthroplasty of the elbow, flexion and extension were excellent. The action of the elbow when below a right angle was weak, due to muscle atrophy. (Fig. 23.)

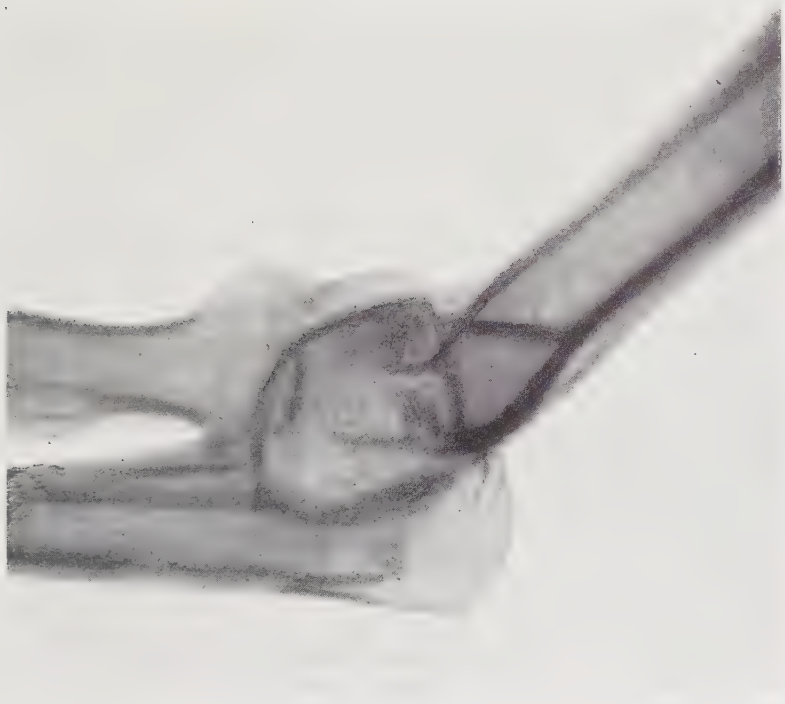

FIG. 24.—Case VII. E. S. Roentgen film showing bony ankylosis. (MacAusland.)

CASE VII.—E. S., aged thirty-five years.

History.—Six years before we saw this patient she had had an acute illness accompanied by fever and pain, and swelling of the joints. At the end of eight months of illness the pain and swelling disappeared from her left shoulder and elbow, so that she was able to feed herself, but she remained in bed for twelve months, and was

then in a wheel-chair for two years. The symptoms continued to subside, and fairly good motion returned to all joints except the right elbow and the right knee. Pain and stiffness continued in these joints at the end of the fourth year of illness. Finally, no motion was possible.

Physical Examination.—A Roentgen film showed ankylosis of the elbow-joint. (Fig. 24.)

Treatment.—August 20, 1913: An arthroplasty of the elbow was done according to our regular technique.

August 27, 1913: The plaster bandage was split for dressing.

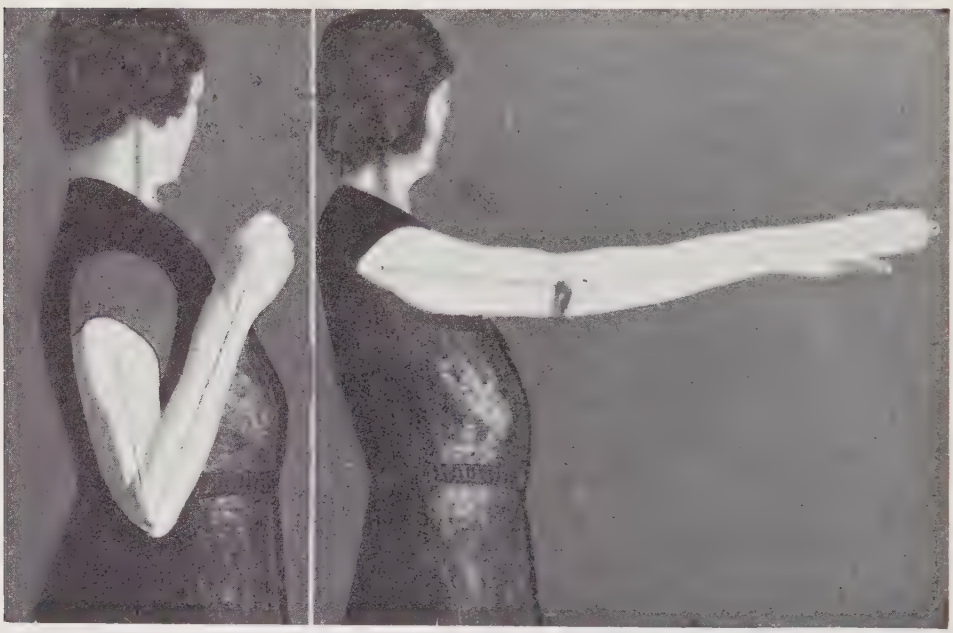

FIG. 25.—Case VII. E. S. Flexion and extension, five years ten months after arthroplasty. (MacAusland.)

September 1, 1913: The wound had healed by first intention, except for a slight discharge on the upper border.

September 4, 1913: Daily manipulations of the elbow were begun.

September 10, 1913: The arm could be extended completely, and flexed to 15 degrees beyond a right angle.

September 15, 1913: Traction was applied for flexing and extending the arm.

October 15, 1913: A manipulation was done under ethyl chloride.

Result.—May 15, 1919: Five years and ten months after operation the patient wrote us that her arm was doing excellent work.

Illustrations show the excellent flexion and extension. (Figs. 25 and 26.)

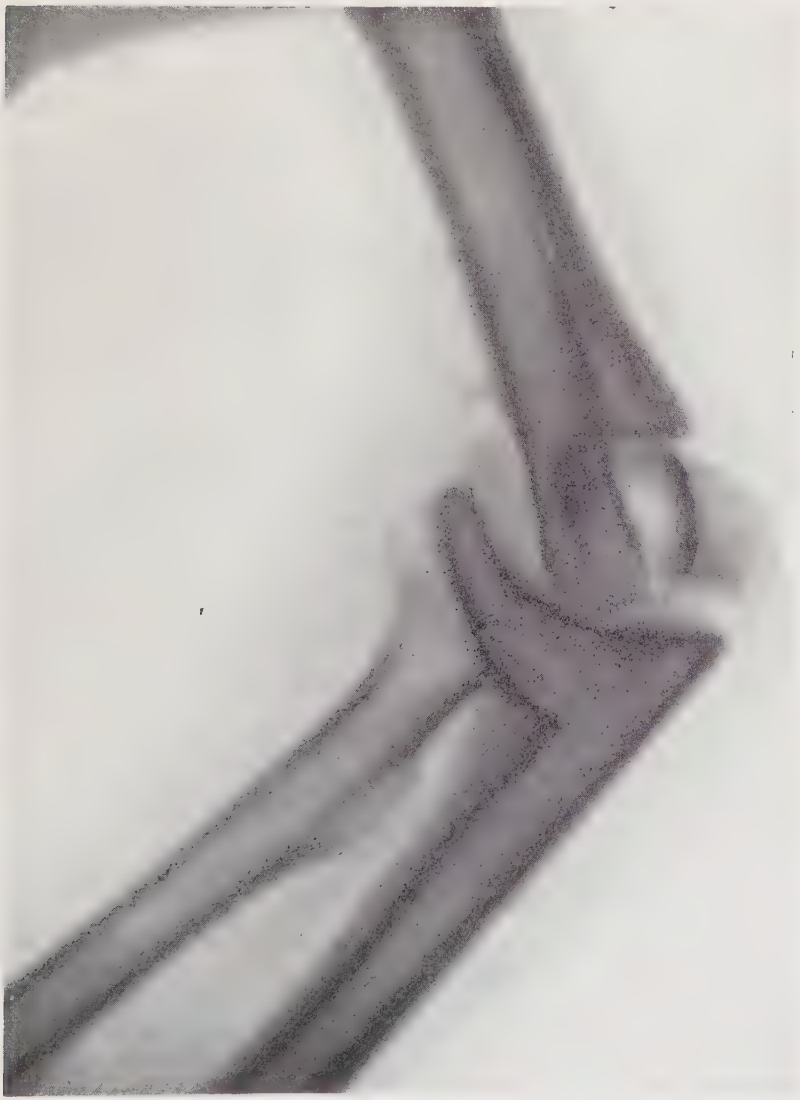

FIG. 26.—Case VII. E. S. Roentgen film showing joint-space, five years ten months after arthroplasty. (MacAusland.)

Résumé of Literature. Since the elbow lends itself well to arthroplastic measures, this joint ranks first in the relative order of frequency of mobilization of the various joints. Whereas the number of attempts to restore motion to the elbow have been numerous, it is

noticeable that most operators have reported only single cases or a very small series of cases. Few surgeons have persevered in developing a technique, which today is recognized as a sound operative procedure that gives consistent good results.

Quénu,[2] in 1902, reported the first arthroplasty of the elbow. It consisted of a wide resection of the inferior end of the humerus, and the insertion of the anterior ligament, doubled with a few fibers from the brachialis anticus. A good functional result was obtained.

Muscle flaps were used in arthroplasty of the elbow by a number of operators, including: Berger;[3] Albarran;[4] Nélaton;[5] Delbet;[6] Ombredanne;[7] Jeannel, Kirmisson and Launay (reported by Dupuy[8]), Pereira;[9] Bazy;[10] Stein;[11] Huguier;[12] Cifuentes;[13] Reiner;[14] Conrad;[15] Tubby;[16] Graff;[17] Moszkowicz;[18] Olivieri;[19] Hohmann;[20] von Lange.[21] The muscle flaps were secured from the triceps, the brachialis anticus, the flexor carpi ulnaris, or the biceps. The results in the majority of the cases were good, and the patients secured serviceable joints. There was slight lateral instability in a few cases. Reiner's series included 28 arthroplasties, 25 of which were reported in full with after-results. Eighteen patients obtained useful arms; 1 joint was flail; ankylosis recurred in 2 cases; and there were several poor results due to extreme atrophy of the muscles and extensive resection of the diseased bone.

Flaps of fat or fatty tissue were used by a few surgeons, among whom were: Schanz,[22] Hoffa,[23] Chaput,[24] Röpke,[25] Vulpius,[26] Payr,[27] Kennedy,[28] Wrede,[29] and Kleinschmidt.[30] Good function resulted in Schanz's single case; in Hoffa's 3 cases; in Chaput's 3 cases; in Röpke's 10 cases; and in Wrede's 4 cases. The reports by the other operators are not complete. Grange[31] secured a good result in a case in which he interposed a flap of fat covered on each side with a piece of Cargile membrane. Fat or fascia was recommended by von Lange,[32] who mobilized 44 elbows, using soft parts for interposition. Thirty-six cases were successful and 8 failed.

Lexer[33] has used fatty tissue flaps in a series of 90 cases, several of which were ankylosed joints. In 84 cases he secured good results, 4 cases were failures, and 2 were questionable.

Murphy[34] was among the first to attempt mobilization of the elbow-joint. In 1904, he reported 2 arthroplasties in which he used his pedicled fascial-flap method. In 1915, his series included 20

cases, many of which, following arthroplasty, had functional and useful joints. Arthroplasties based upon the Murphy method or modifications of it were reported by Hoffa,[23] Scudder,[35] Wille,[36] Weiner,[37] Edmunds,[38] Neff,[39] Harris,[40] Darling,[41] Simon,[42] Vulpius,[26] Gilbert,[43] Ashhurst,[44] Brown,[45] Steindler,[46] Roysing,[47] Plummer,[48] Thomson,[49] Prando[50] and Kerr.[51] By far the majority of the patients secured good serviceable elbows.

Hössly[52] reported 16 cases, in 14 of which fascia-fat flaps were used, and in 2 of which resections were done. Seven recovered almost normal function, 5 showed great improvement, and 4 results were poor. Ringel[53] and Vulpius[26] used free flaps of fat and fascia.

A pedicled flap method, which has been used to a certain extent by different surgeons in Italy, was devised by Durante.[54] He himself reported 4 good results. Leotta,[55] in 1908, referred to 13 operations performed according to this technique in the Clinic of Rome. Francini[56] reported 2 successful applications of the method. Pomponi[57] advocated Durante's method, and cited 1 case in which the motion recovered was almost normal. Crosti[58] used a modification of Durante's method with success.

Baer[59] has reported only 3 elbow arthroplasties. His results have not been successful, and have led him to believe that the use of his membrane method is least favorable in the elbow-joint. Osgood[60] tried Baer's membrane in 1 case, securing good motion, except for some lateral mobility.

Following the first successful attempts with fascia as the interposed material, this substance began to be used more frequently than any other in elbow arthroplasty. Among the operators who have interposed fascial flaps are: Thom,[61] Pupovac,[62] Putti,[63] Exner,[64] Turner,[65] Whitman,[66] von Lange,[32] Ryerson,[67] Ceccarelli,[68] Rocher,[69] Silfverskiöld,[70] Campbell,[71] Odelberg,[72] Anglesio,[73] Dillehunt,[74] and Meyerding.[75] Good function was obtained in the majority of cases.

Putti's[63] latest report on the elbow, issued in 1922, gives a total of 38 arthroplasties of the elbow, which had been performed since his previous report in 1912 when 12 cases were published. Putti uses Kocher's incision and inserts a flap of fascia lata. Several of his patients were able to return to military service.

Campbell,[71] in 1924, reported a series of 14 arthroplasties of the elbow. Four excellent results were obtained; 5 good results, with

motion of 40 to 50 degrees; 3 cases were failures; 2 cases had been mobilized too short a time to judge the outcome.

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ARTHROPLASTY OF THE KNEE-JOINT.

Arthroplasty of the knee-joint is universally admitted to present a more difficult problem than mobilization of any of the other large joints. This is because the knee anatomically is a complex joint, supported by ligaments located both within and without the joint. Furthermore, it is a weight-bearing joint. To be satisfactory, the newly-formed knee not only must be functional from the point of view of motion, but the joint must also be absolutely stable in order to adapt itself to weight-bearing. Moreover, there must be the assurance that the knee will be free from pain and sensitiveness. Unless there is a reasonable chance that an arthroplasty will result in a stable, painless knee with increased motion, it is far better not to attempt mobilization. A knee ankylosed in good position (5 to 8 degrees flexion) is a functional member, whereas an unstable knee is a handicap. Even when an efficient brace is worn to protect a hypermobile joint, the knee is constantly subject to undue strain, and in time arthritic changes with accompanying pain and soreness will develop.

During the last ten years definite progress has been made in arthroplasty of the knee-joint—a progress that is due largely to the splendid work of Professor V. Putti, of Bologna. The percentage of

failures among the early knee arthroplasties was high. Lateral mobility resulted in many cases and re-ankylosis occurred frequently. The fear of obtaining an unstable joint has now been overcome by the refinement of the technique of arthroplasty, particularly in the removal of the correct amount of bone, in the remodeling of the articular ends, and in the preservation of the ligamentous structures. Then, too, as the importance of the selection of cases suitable for arthroplasty has come to be more fully appreciated, and the indications better understood, the prognosis for arthroplasty of the knee has correspondingly improved. As yet, there is no standard technique, but the procedures in use offer much promise.

Our own experience in attempting to mobilize the knee-joint has been similar to that of other operators. Our first 3 cases were failures and for a time we decided it was best to discontinue knee mobilizations. Finally, however, we worked out a technique that proved satisfactory, and today we are obtaining consistently good results by the use of this method.

Indications and Contraindications.—Mobilization of a knee-joint is advised only after serious study of the given case. In general, indication for arthroplasty depends upon the degree of disability the patient suffers because of the stiff knee. If the case is one of single ankylosis in good functional position (5 to 8 degrees flexion), the limb is a comparatively useful member. In such cases, the decision to mobilize the knee is usually based upon the patient's need of further mobility in his profession or occupation. In an occasional case operation is considered for esthetic reasons, since the knee even when stiff in good position is a handicap, and the leg is in an ungainly position, particularly when sitting. The awkwardness is more disturbing to women than to men, especially to young women, who may be socially handicapped.

If, on the other hand, the joint is ankylosed in a position of deformity, or if the knee has limited motion that subjects it to constant strain, arthroplasty is always to be considered. In double knee ankylosis, mobilization of at least one knee is definitely indicated; or if there is a combination of a stiff knee and hip on the same side, indications for operation are pressing.

The origin of the ankylosis; the possibility of the retention of any infectious foci; the condition of the bone, skin, and musculature; the age of the patient, as well as his social and occupational circum-

stances, are important factors to be considered. (See General Discussion on Indications and Contraindications, p. 49.) The ages between twenty and forty years are best for operation.

The condition of the extensor muscle group of the knee must be carefully estimated before proceeding with mobilization, for unless good extensor muscles are present, an arthroplasty will be of no value. To make sure that these muscles are in good condition, it is well for the patient to practise contraction of his thigh muscles for several months before operation. If the knee is fixed in flexion, it is also of benefit to stretch the hamstrings as much as possible before the arthroplasty is done.

The Distribution of the Ankylosis. In intra-articular ankylosis of the knee-joint, the type with which we are chiefly concerned, a complete bony fusion of the patella, femur, and tibia is most commonly found. In some cases there may be a tibiofemoral union, with a mobile patella. In others, the patella may be fused with the femur, and the tibiofemoral joint is apparently free. In still other cases, one condyle may be fused with its tuberosity, whereas the other half of the joint is apparently normal.

Some operators modify their technique to meet the different conditions presented by the distribution of the ankylosis, but except in the case of fusion between the patella and the femur with the tibiofemoral joint free, the writers use the same technique in all cases. In patellar ankylosis we perform a subpatellar arthroplasty, and provided the cartilages of the tibiofemoral articulation are found to be normal, we do not disturb this joint.

The Correction of Deformity before Operation.—Notwithstanding that all lesions of the knee-joint should be treated in the position of functional strength (5 to 8 degrees flexion), practically every ankylosed knee that comes to the attention of the surgeon is in a position of deformity. (Fig. 27.) It is not unusual to see three deformities present—flexion, knock-knee, and subluxation. If malposition is marked and of long-standing so that the posterior capsule and hamstrings are contracted, deformity must be corrected before arthroplasty is attempted. Otherwise, the postoperative treatment would present a complicated problem in regaining extension.

Operative Technique (Writers').—The usual preparation is given to *both* legs from the ankle to the groin. In our opinion, it is best to

remove the fascial flap from the well leg, not only to minimize the extent of the operation on the ankylosed leg, but also to make possible the removal of as much fascia as is needed, without disturbing the external support of the operated knee-joint.

The operation is performed under thorough hemostasis by using the Esmarch bandage.

FIG. 27.—Ankylosis of knee in 30 degrees flexion—the position of deformity.

A longitudinal incision is made, beginning 3 to 4 inches above the patella over the middle of the quadriceps tendon, extending downward in a straight line over the center of the patella and its attachment, and terminating 1 to 2 inches below the tibial tubercle. (Fig. 28.) The skin and superficial fascia are dissected back on each

side of the incision for a distance of 3 to 4 inches to expose the deep fascia and the quadriceps tendon and muscle.

A second incision is made through the fascia, quadriceps tendon, and capsule. This incision is in the shape of an inverted short-stemmed goblet. The top of the stem begins about 3 inches above the upper edge of the patella and extends downward for about 1

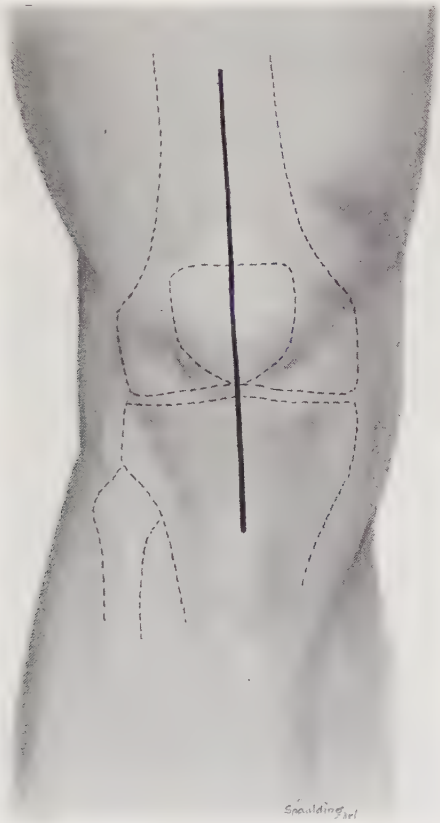

FIG. 28.—Knee arthroplasty. Line of skin incision. (MacAusland.)

inch. Two curved incisions proceed from the lower end of this stem, following a goblet in outline; the outer one terminates over the outer tuberosity of the tibia and the inner over the inner tuberosity of the tibia. (Fig. 29.) The incision in the quadriceps tendon provides for the lengthening of this structure, a step usually necessary when the knee has been stiff in extension for a long period. If the

knee has been stiff in flexion, lengthening of the tendon is not so vital, or only a slight elongation may be required.

The capsule, the periarticular structures, and the patella are dissected downward. The patella is chiseled from the femur, exposing the tibiofemoral joint. Some operators detach a piece of

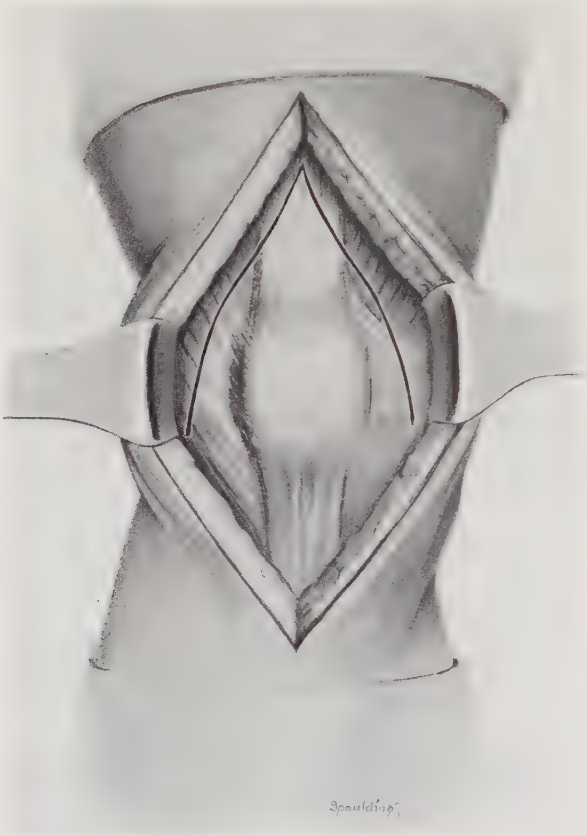

FIG. 29.—Knee arthroplasty. Incision through fascia, quadriceps tendon, and capsule. (MacAusland.)

the tibial tubercle in order to increase the exposure, but we have not found this step necessary when the quadriceps is lengthened. Furthermore, there are many difficulties attending the removal of a piece of the tubercle, such as delayed or faulty union, which complicate the convalescence. The ligamentous structures are freed from their attachment to the tibia and the femur.

Probably one of the most difficult problems to solve in arthroplasty of the knee is the treatment of the patella, as not infrequently motion and stability are obtained between the femur and the tibia, but the patella reunites and the joint becomes stiff. The patella is usually hypertrophied and requires narrowing. This is done by removing a third of it longitudinally from the outer and inner

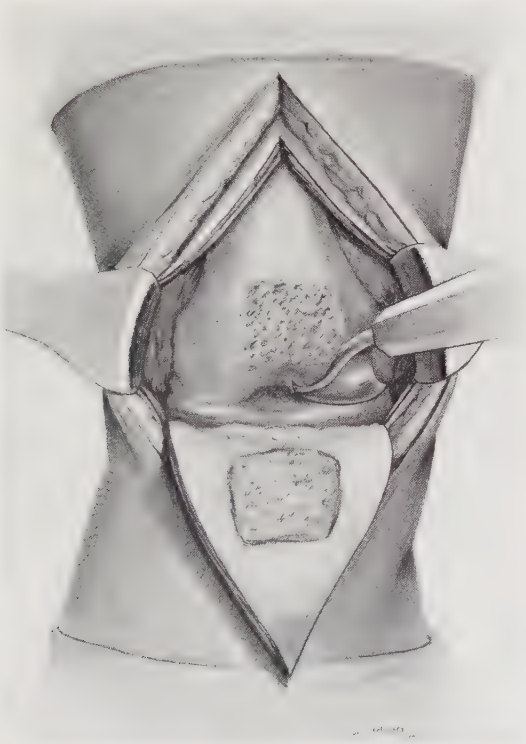

FIG. 30.—Knee arthroplasty. Displacement of patella and freeing of joint-line. (MacAusland.)

surfaces, and about one-third from the joint surface of the remaining section. The entire patella should never be removed. The joint capsule is then pulled over the patella and sewed.

Attention is now given to freeing the joint-line and modeling the new joint surfaces. (Fig. 30.) Putti's instruments are excellent for this purpose. (Fig. 31.) Great care is taken to follow the natural contour of the joint as closely as possible. The tibia is

separated from the femur by means of a gouge, the diameter of which corresponds to that of the femoral condyle in the adult. First the external condylar mass is cut, and then the internal, with the instrument inclined at such an angle that an approximate semicircular convexity is formed. As the operation proceeds, an assist-

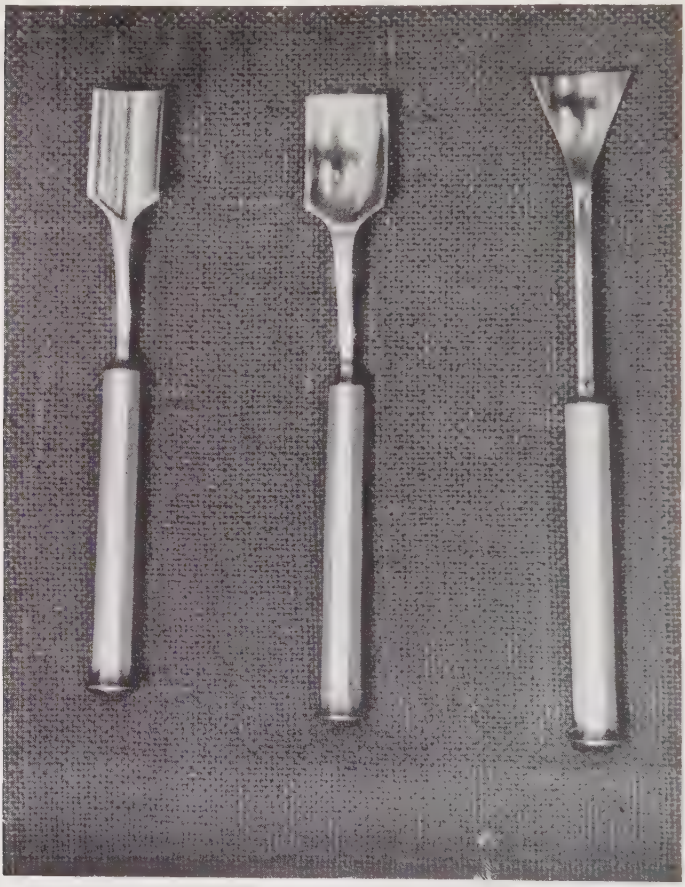

FIG. 31.—Putti chisels.

ant flexes the knee so that the remaining lamellæ uniting the epiphysis of the posterior region are divided.

By means of the same gouge that is used in freeing the joint-line, about 1 cm. of bone is removed from the femoral surfaces. The tibial and femoral surfaces are then remodeled to conform as closely

as possible to the normal contour of the joint. Two concavities, corresponding in shape to the outline of the femoral condyles, are created in the tibia. To ensure stability, it is important to leave a well-defined spine between these cavities, which corresponds to the intercondylar notch.

After the joint surfaces have been modeled, the articular ends are fitted to make sure that sufficient bone has been removed. The surfaces must glide smoothly without any irregular hitches during flexion and extension of the knee. If necessary, more bone may be removed.

A space into which the patella will articulate is cupped out of the upper surface of the femur.

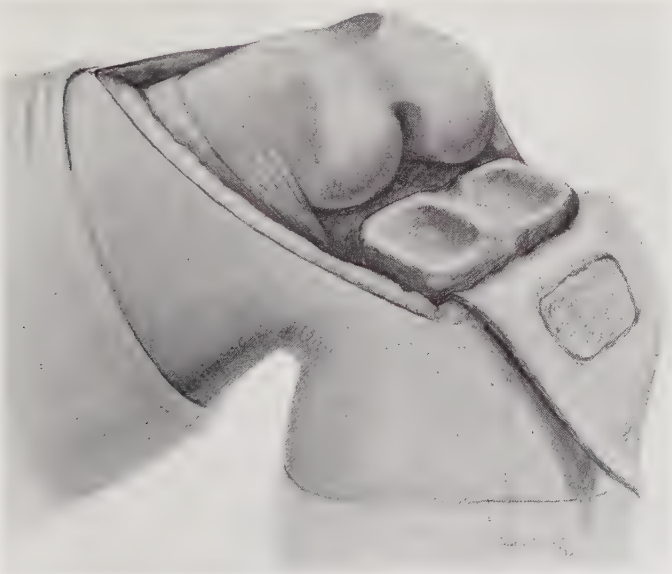

FIG. 32.—Knee arthroplasty. Remodeled femoral and tibial surfaces. Note the intercondylar notch. (MacAusland.)

Files and rasps are used to smooth the surfaces. This filing, in addition to smoothing the edges, drives a bone dust into the open spaces, which aids in controlling hemostasis, and by roughening the surfaces of the resected edge causes the aponeurosis of the fascial transplant to adhere firmly. (Fig. 32.)

The next step is to remove from the opposite leg a large piece of

fascia lata of sufficient size to cover both condyles, both tibial cavities, and the under surface of the patella. The fascia nearest to the knee on the outer side of the leg is thickest and most serviceable. The operator begins to suture the long flap over the tibial cavities at the anterior surface of the tibia. He then allows the flap to drop back into the popliteal space to a point about $2\frac{1}{2}$ inches up the posterior surface of the femur. The flap is fixed to the lateral surface of the tibia with several interrupted sutures. Then the flap is swept around the femur and wrapped over its anterior surface for about $2\frac{1}{2}$ inches, and tied tightly in place with a purse-string suture. The remaining part of the flap is then turned down and sutured to the top surface of the tibia. (Fig. 33.)

FIG. 33.—Knee arthroplasty. Attachment of fascial flap. (MacAusland.)

The deflected flap consisting of the patella, capsule, quadriceps, and fascia is replaced. The elongated quadriceps and the capsule are strongly sutured, and the skin is closed with interrupted catgut. (Fig. 34.) A plaster bandage or intrinsic traction splint is applied from the toe to the groin, with the knee in 35 to 40 degrees flexion. The leg is placed in an elevated position in bed. Opiates are often necessary and may be used freely.

It will be noted that the lateral ligamentous apparatus is carefully preserved. This step is one of the most important in knee-joint arthroplasties. Provided this fundamental is carefully observed, and provided the details of technique are carried out precisely, a stable joint will result. Hence, there will be no necessity for secondary operations involving the use of strips of fascia lata to restore stability, procedures that are advocated by several operators.

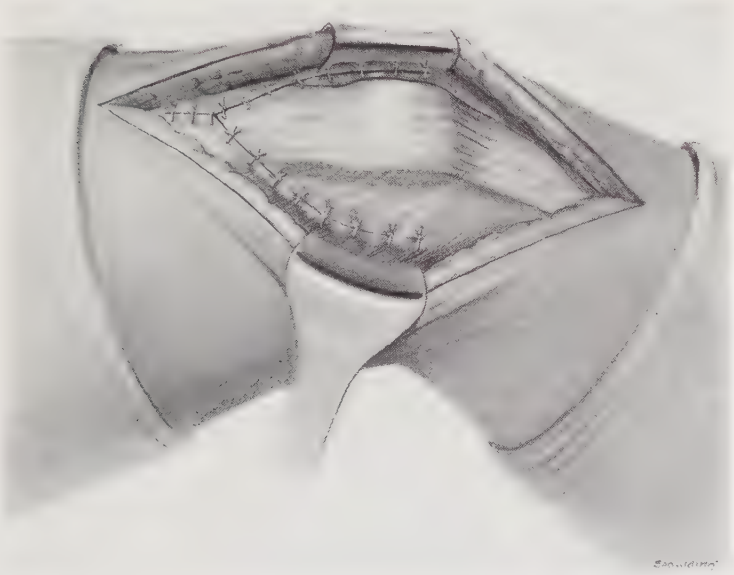

FIG. 34.—Knee arthroplasty. Suture of capsule and fascia. (MacAusland.)

After-treatment.—The temperature, pulse, and pain are watched for any signs of infection.

If a plaster bandage has been applied, it is split for dressing about two weeks after operation, and the leg is placed in a ring caliper traction in 35 degrees flexion. This caliper is so arranged that knee motion is possible.

By means of an overhead pulley, the patient begins passive motions while in bed, carrying them out usually two or three times a day. The movement should be gentle at first and increased gradually. The patient by controlling the arc of motion himself eliminates much of the voluntary spasm. Active movements are attempted about the third or fifth week, and if they can be done without pain

they are continued. Massage of the thigh and calf is begun in five or six weeks. About the sixth week the patient can usually walk with crutches. No actual weight-bearing is allowed until the lateral ligaments have tightened. In the first attempts at weight-bearing, a caliper is of help to relieve pain and sensitiveness and to protect the knee from strain.

FIG. 35.—Case VIII. F. O'K. Showing weight-bearing twelve years after arthroplasty. (MacAusland.)

CASE VIII.—F. O'K., aged nineteen years.

History.—In 1909 this patient suffered an acute Neisserian infection in the left knee. The joint was opened and treated. Following the attack the knee was in good position, but there was no motion between the tibia, femur, and patella.

Complaint.—Stiff knee.

Treatment.—Manipulations were carried out, but they were not successful in restoring motion.

December 14, 1910: An arthroplasty was performed.

FIG. 36.—Case VIII. F. O'K. Showing weight-bearing twelve years after arthroplasty. (MacAusland.)

December 23, 1910: The patient was out of bed. Daily dressings were being done.

January 5, 1911: The plaster bandage was removed and a posterior shell applied.

January 7, 1911: The patient was walking with crutches and putting a little weight on the foot.

January 19, 1911: The patient was discharged from the hospital with the leg in a leather leglet with limited motion. Daily stretchings and hot fomentations were to be continued.

Result. January 23, 1923: Twelve years after arthroplasty the patient had complete extension and 95 degrees motion in flexion.

FIG. 37.—Case VIII. F. O'K. Ninety-five degrees flexion, twelve years after arthroplasty. (MacAusland.)

The knee was absolutely stable. The quadriceps had good power. The patient told us that he had had no trouble since operation, and that he could do everything with the knee. Sometimes he had to think which was the operated member. (Figs. 35, 36, 37, 38 and 39.)

Since that time the patient has continued to have a normal functional knee.

FIG. 38.—Case VIII. F. O'K. Antero-posterior Roentgen film, twelve years after arthroplasty. (MacAusland.)

CASE IX.—C. B., aged fifty years.

History.—In 1920 this patient was struck across the right thigh about 4 inches above the knee-joint. Swelling appeared immediately after the accident. The patient continued to work, standing on the leg, for several weeks. Then his physician aspirated and drew off some fluid, the nature of which the patient did not know. After three aspirations the knee-joint began to swell and

became very painful. Later, the knee-joint itself was aspirated and drained several times. For a year the patient was completely disabled. For three years the knee had been stiff. Small pus pockets

Fig. 39.—Case VIII. F. O'K. Lateral Roentgen film, twelve years after arthroplasty. (MacAusland.)

were drained frequently, but the knee had remained healed for eleven months when the patient was seen by the writers.

Complaint. Stiff knee. As the patient was a miner, he had been unable to follow his occupation since the injury.

Physical Examination.—The right knee was ankylosed, allowing 15 degrees flexion and 15 degrees extension when the patient put his foot on the floor and pushed against the knee. There was no

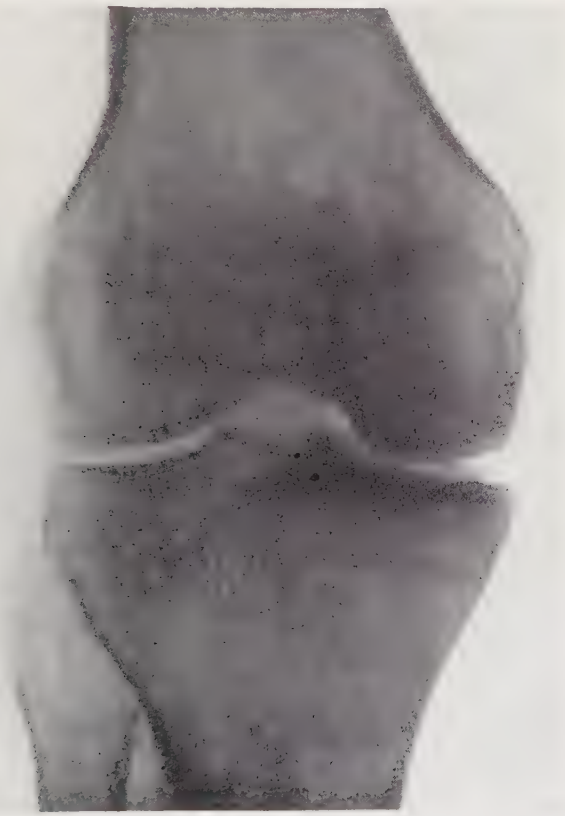

FIG. 40.—Case IX. C. B. Anteroposterior Roentgen film showing area of firm fibrous ankylosis. (MacAusland.)

voluntary motion. (Figs. 40 and 41.) There were many scars on both the inner and outer sides of the knee. The muscles of both the thigh and leg were considerably atrophied. The patient's general health was excellent.

Treatment.—April 29, 1924: An arthroplasty was performed.

May 6, 1924.—The plaster bandage was removed. The wound had healed nicely. The leg was placed in a splint so that the knee

could be moved. At this time the patient had 45 degrees motion without pain.

May 19, 1924: The patient had 65 degrees motion in flexion and almost complete extension. The splint was removed. Gentle massage and hot fomentations were begun.

May 27, 1924: Complete extension was possible. The patient had 30 degrees motion by his own control and 55 degrees forced motion. He was walking with crutches and suffered no discomfort.

FIG. 41.—Case IX. C. B. Lateral Roentgen film showing area of ankylosis before mobilization. (MacAusland.)

Result.—September 13, 1924: Six months after operation the patient had about 65 degrees flexion and complete extension. There was still some thickening about the joint, which would undoubtedly disappear, with a corresponding increase in flexion. The patient was walking with a cane. The knee was absolutely stable.

April 24, 1925: Roentgen films show the joint surface one year after arthroplasty. (Figs. 42 and 43.)

August 25, 1927: Three years and four months after arthroplasty the patient had motion to nearly a right angle. There was good stability. The result was an excellent functional one. (Figs. 44 and 45.)

Fig. 42.—Case IX. C. B. Antero-posterior Roentgen film, one year after arthroplasty. (MacAusland.)

Fig. 43.—Case IX. C. B. Lateral Roentgen film, one year after arthroplasty. (MacAusland.)

Fig. 44.—Case IX. C. B. Showing weight-bearing, three years and four months after mobilization. (MacAusland.)

Fig. 45.—Case IX. C. B. Showing flexion to nearly a right angle, three years and four months after mobilization. (MacAusland.)

Case X.—S. T., aged fifty years.

History.—Eight years before we saw the patient he had suffered a streptococcic infection from his tonsils. His elbow and knee were affected. The joints were opened and drained.

Complaint.—Stiff knee.

Physical Examination.—The left knee was ankylosed, allowing only 10 degrees motion from 175 degrees. There was one scar on

Fig. 46.—Case X. S. T. Antero-posterior Roentgen film taken one year after arthroplasty. (MacAusland.)

the inner side of the knee and there were two on the outer side. The vastus externus was tied down into one of the scars. Roentgen films showed a clean fibula, but the patella and the posterior part of the tibia were a little roughened. The patient, a rancher, was unable to attend properly to his work because he was unable to ride horseback. In spite of his age, we advised arthroplasty, as

all other factors were conducive to success. The patient's general health was excellent.

Treatment.—January 10, 1925: An arthroplasty was performed.

January 14, 1925: The patient had been somewhat uncomfortable during the past two days from abdominal distention and gas.

January 19, 1925: When the knee dressing was done there was evidence of pus burrowing under the flap of the knee proper. Dakin's tubes were inserted. The abdominal distention continued to come and go, and the patient was very uncomfortable at times. The possibility of an abdominal condition was considered.

FIG. 47.—Case X. S. T. Lateral Roentgen film taken one year after arthroplasty. (MacAusland.)

January 21, 1925: There was considerable pus under the flap covering the knee, but there was no evidence of pus in the knee-joint itself. A small area was opened up through the flap over the knee, and the wound carefully syringed with hot normal salt solution. The plaster was removed, a posterior ham splint was fitted, and side splints were applied. Four Dakin tubes were inserted and irrigation was done every two hours.

January 23, 1925: Considerable pus was coming from the inner side of the circular incision over the knee, and there was also some discharge on the outer side from the skin flap. There was no definite indication of pus within the knee. The wound was carefully washed out with wine-colored iodine solution, and three large tube drains were placed in the discharging sinuses. The general condition seemed to be improved.

FIG. 48.—Case X. S. T. Showing weight-bearing two years after arthroplasty. (MacAusland.)

January 24, 1925: A Jones posterior splint was applied. There was a slight tendency to knock-knee, which was to be watched and corrected.

January 27, 1925: The patient was having difficulty with tympanites. Stools were bloody. The knee was washed out, and one tube was put into the posterior joint space, one into the anterior space, and one was inserted on the inner side under the skin flap.

January 28, 1925: Some pus was found in the region of the joint proper. The wound was irrigated with weak iodine solution. The splint was adjusted to prevent knock-knee. The abdomen was very much distended, and the pulse was around 120 and rather poor in

quality. There seemed to be a suggestion of edema around the anterior surface of the chest. The stools continued to be bloody, dark, and tarry.

January 29, 1925: An operation was performed for the abdominal trouble, and free air and fluid were found in the abdominal cavity. A Mixter tube was inserted into the intestine, and the pelvis drained.

February 4, 1925: The surgical and medical aspects of the case were progressing favorably. The distention was being relieved. There was still one tube in the posterior space of the knee and irri-

Fig. 49.—Case X. S. T. Showing flexion two years after arthroplasty. (MacAusland.)

gations were being done every two hours. Traction was being continued to prevent knock-knee. During the next two months all infection in the knee was eliminated by irrigation. A sloughing piece of fascia was removed. On *March 2, 1925*, the patient was encouraged to move the knee a little. There was about 10 to 15 degrees lateral mobility. Traction was to be continued on the foot and lateral traction was to remain on the knee.

March 15, 1925: The patient was walking with crutches a little each day and beginning to bear weight.

Result.—February, 1927: Two years after operation the patient had flexion to a right angle, and he could extend his leg completely

from the horizontal. The joint was stable and painless. He was able to ride horseback. (Figs. 46, 47, 48 and 49.)

CASE XI.—R. H., aged twenty-four years.

History.—June 8, 1924: This patient suffered a severe contusion and comminuted condylar fracture of the lower left femur, about 3 to 4 inches above the joint.

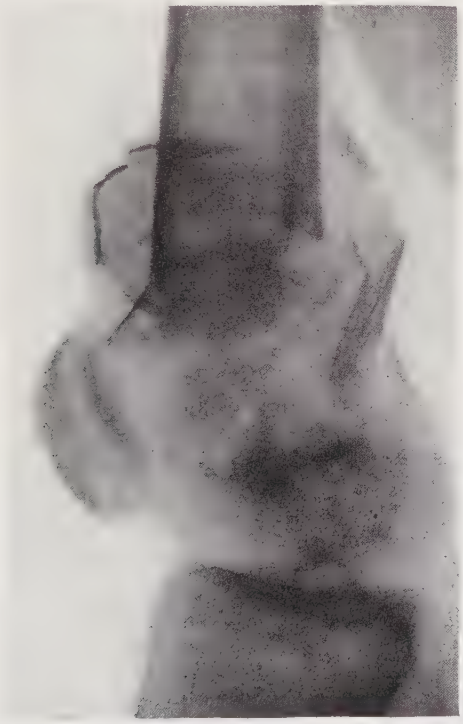

FIG. 50.—Case XI. R. H. Lateral Roentgen film showing fusion of patella to lower femur. (MacAusland.)

November 13, 1924: Following proper treatment of the fracture the motion of the knee was limited, only 10 degrees in flexion being possible from the extended position. There was lateral motion of 8 to 10 degrees. A Roentgen film (Fig. 50), taken *August 21, 1924,* showed the patella adherent to the lower femur.

Complaint.—Stiff knee.

Treatment.—November 20, 1924: A subpatellar arthroplasty was done.

January 8, 1925: A leather leglet was fitted. The patient was encouraged to walk and to have sun exposures for the knee wound.

Fig. 51.—Case XI. R. H. Showing weight-bearing four years after arthroplasty. (MacAusland.)

Fig. 52.—Case XI. R. H. Showing flexion to 90 degrees, four years after arthroplasty. (MacAusland.)

February 5, 1925: The knee was stable from side to side. There was 35 to 40 degrees painless motion.

February 26, 1925: There was 70 degrees motion. A shade of knock-knee was to be overcome by correction of flat feet.

March 14, 1925: The patella was movable in all directions. The knee was stable. The patient was able to extend the leg voluntarily to within 15 degrees of full extension. Here the patella seemed to stop. She walked well without the leglet.

May 6, 1926: Small adhesions were broken up.

Result.—January, 1928: The patient had a stable and perfectly functional knee. Extension to 180 degrees and flexion to 90 degrees were possible. There was no pain in the joint. (Figs. 51 and 52.)

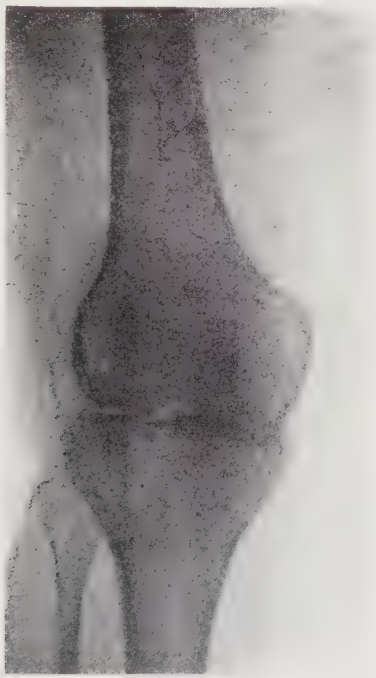

FIG. 53.—Case XII. E. P. Roentgen film showing ankylosis of the femur and tibia. (MacAusland.)

CASE XII.—E. P., aged thirty years.

History.—September, 1921: The patient suffered a very acute infectious process in the right knee, probably metastatic in origin from the tonsils.

Complaint.—Stiff right knee and occasionally back pain.

Physical Examination.—The right knee was ankylosed in a few degrees hyperextension, with a slight knock-knee deformity. The

patella was freely movable. The quadriceps had good power. Roentgen films showed destruction of the articular surfaces of the femur and the tibia. The patellar surface of the femur was not involved. (Fig. 53.)

Treatment.—March 5, 1925: An arthroplasty was performed.

March 16, 1925: The plaster bandage was removed. The wound was healing by first intention.

March 21, 1925: Traction was applied with a Thomas ring splint to allow motion. The patient could obtain 20 degrees motion at this time.

FIG. 54.—Case XII. E. P. Showing flexion two years after arthroplasty. (MacAusland.)

April 4, 1925: There was motion to 35 degrees. The joint was stable.

April 27, 1925: The patient was walking with crutches and getting motion to within the limits of the leather leglet, without pain. She was beginning to bear weight on the forefoot.

May 15, 1925: Under gas the leg was flexed gently to about 35 to 40 degrees.

Result.—April, 1927: The knee was in splendid shape. The function was good. There was 90 degrees motion without pain. (Figs. 54, 55 and 56.)

Résumé of Literature. The difficulty of mobilizing the knee-joint from an anatomical standpoint, and the unserviceable joints that usually were obtained, caused many of the earlier experimenters in the field of arthroplasty to hesitate to attempt mobilization of the knee. Cramer[2] seems to have been the first to report a series of knee arthroplasties. His technique included the interposition of muscle flaps. Of the 7 operations he reported, all of which were performed in ankylosis of the patella, 6 resulted successfully.

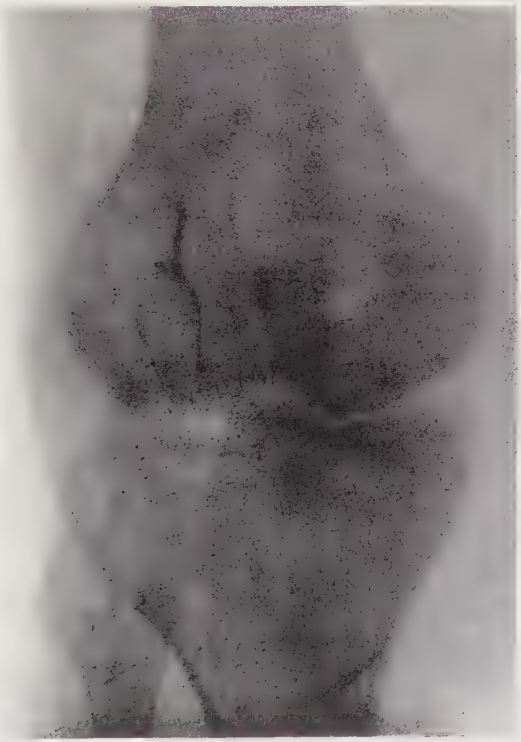

FIG. 55.—Case XII. E. P. Antero-posterior Roentgen film showing joint-space two years after arthroplasty. (MacAusland.)

Murphy[3] was another early experimenter in the field of knee arthroplasty. He first used his pedunculated fascial-flap method in a case of double knee ankylosis. In performing the arthroplasty, Murphy used two flaps: One large flap, consisting of a layer of fascia lata to which was attached a thin layer of muscle, was dissected from the outer surface of the vastus externus, and drawn into

the joint by means of heavy catgut sutures; the other, smaller in size, was dissected free from the vastus internus and placed between the patella and the femur. Five months after the first intervention, an arthroplasty was performed upon the other knee. The end-result was good. About three years after operation, the patient was doing work that necessitated standing twelve hours a day.

Fig. 56.— Case XII. E. P. Lateral Roentgen film showing joint-space two years after arthroplasty. (MacAusland.)

In 1904, Murphy published a report of 5 knee arthroplasties inclusive of the 2 operations mentioned above. The third case resulted in fibrous ankylosis following suppuration. The outcome in the fourth case was excellent, the patient being able to use his leg freely without pain. Good motion also was obtained in the fifth case.

Hoffa[4] was among the first to attempt mobilization of the knee-joint. In 1906, he reported 8 operations for tibiofemoral ankylosis,

in which he used pedicled and free flaps of fat. His results were unfavorable, and the small amount of motion obtained hardly justified the attempt at mobilization.

Beginning in 1912, mobilization of the knee-joint was attempted more frequently. Among the operators who persisted in their endeavor to secure serviceable and functional knees by arthroplasty were: Murphy,[3] Payr,[5] Lexer,[6] Campbell,[7] Putti,[1] Baer,[8] and Albee.[9] In the majority of cases, except in those reported by Baer and Lexer, flaps of fascia lata, with or without a layer of fat and pedicled or free, were used for interposition. Baer used chromicized pig's bladder for flaps. Lexer preferred subcutaneous fatty tissue.

Between 1912 and 1917, Murphy reported several knee arthroplasties. Pedicled flaps were used in the majority of the operations. Eight excellent results were reported, the patients having a good range of motion and walking well. One patient secured 20 degrees flexion, but extension was impossible, due to the inactivity of the quadriceps. Four records were incomplete, but the outlook was favorable in 2 of the cases. Four cases, in 2 of which free transplants had been used, were failures. Another patient left the hospital with 45 degrees of motion, but she was of an hysteric nature and refused further treatment. Another case was an unfavorable subject in the beginning and suppuration developed.

In regard to the technique that Murphy used, in his early cases he interposed transplants of fascia lata taken from the vastus externus. Later, he used two flaps of fat and fascia, one being lifted from the inner, and one from the outer aspect of the knee. He also changed his method of incision from vertical cuts on the inner and outer sides of the patella to a U-incision. The patella was treated in one of four different ways; by placing a flap under it, by splitting it into two parts and turning the upper part under the lower, by rotating it so that the upper surface became the articular surface, or by covering the under surface of the patella and the entire surface of the femur with a fascial graft, which was detached from the trochanteric zone.

Comment.—There is some question as to whether the joints were stable in all these cases that allowed good motion. Some of Murphy's cases that we had the opportunity to examine could not be said to have had functional knees, although they had ample motion.

Arthroplasties by the Murphy method, or modifications of it, have been reported by Whitacre,[10] Neff,[11] Owen,[12] Quigley and Stevenson,[13] Pringle,[14] Rovsing,[15] McKenna,[16] Thomson,[17] Wheeler,[18] Zeller,[19] Finochietto,[20] Le Fort,[21] Lenormant,[22] Mauclaire[23] and Appel.[24] Several good results as to function were reported, but lateral movement was often present and re-ankylosis was not uncommon.

Payr,[5] at the *Deutsche Gesellschaft für Chirurgie* of 1912, reported 12 knee arthroplasties, 4 of which were performed in cases of fibrous ankylosis and 8 in the bony variety. The results in 6 of the cases were good and the others were mediocre. In 1914, Payr reported a second series of 13 arthroplasties, 9 of which resulted in good function. In 1921, Hohlbaum[25] reported the results of mobilizations that had been done at Payr's Clinic. The report included 85 knee-joints. Successful results were obtained in 78 per cent of the cases and failures occurred in 22 per cent. Twenty-five of the cases obtained excellent function, 23 obtained good function, 15 were unsatisfactory, and in 16 cases ankylosis recurred. In Payr's method, flaps of either fascia or fat are used for insertion. When fascia is interposed Payr has found pedunculated flaps most practical. Freely transplanted fat has proved just as suitable.

Simon,[26] Schloffer,[27] and Ingerbrigsten[28] have secured good results by the use of Payr's method.

In 1917 Baer's[8] knee arthroplasties totaled 28. Seven of these operations were for fibrous ankylosis between the femur and the patella, or between the femur and the tibia. Four cases secured good motion amounting to 75, 40, 50, and 55 degrees respectively. Three cases were failures. Five of the arthroplasties, which were performed for bony ankylosis between the patella and the femur with fibrous union between the tibia and the femur, resulted in excellent motion. Of 16 cases of bony ankylosis between the patella and the femur and between the femur and the tibia, 10 were successful.

McCurdy[29] obtained excellent results in 3 cases in which he interposed Baer's membrane. In one case in which both patellæ were ankylosed as the result of fractures, complete extension and 90 degrees flexion were obtained in the right knee and 80 degrees flexion in the left knee. In the second case complete extension and flexion to 90 degrees were present ten weeks after operation. In the third case complete extension and flexion to 80 degrees resulted. Indications were that the cases would continue to improve.

Osgood,[30] in 1913, reported 4 cases of knee arthroplasties in which Baer's membrane was interposed. In general, good or fair motion was secured, but there was some lateral mobility, due undoubtedly to faulty technique.

Lexer,[6] in 1925, reported his number of knee arthroplasties as 79. Sixty of this group were successful cases, the mobility being normal or sufficient for use. Thirteen results were failures and 6 were questionable. The causes of the poor outcome were either latent infection or lack of sufficient after-treatment. Lexer's technique is as follows: An anterior bow-shaped incision is made. The fascial reënforcements and lateral margins are cut through longitudinally. The tuberosity of the tibia is chiseled off in such a way that it remains connected with the patellar ligament. If the patella is adherent, it is separated from the femur. In the restoration of the joint surfaces, Lexer follows the procedure of Murphy. A fatty tissue flap taken from the thigh is used to cover the joint-ends. A lining for the patella is provided by a pedicled or free fatty-tissue flap.

Jahn[31] has also reported an arthroplasty in which free strips of subcutaneous adipose tissue were used. His operation was based on the method of Schanz. The case was one of ankylosis at a right angle, due to tuberculosis. Following operation the patient could walk very satisfactorily, the knee having flexion of 50 degrees, complete extension, and good stability.

From Kukula's Clinic in Prague comes a report by Jirasek[32] on the use of omental fat, subcutaneous tissue, and free fascia in 13 arthroplasties of the knee. There was a complete return of mobility in 77 per cent.

Campbell[7] has issued reports on four series of knee arthroplasties, including a total of 111 cases. As he has gained experience, the percentage of good results has increased. In his first report, comprising 24 cases, the results were far from satisfactory; his second report, on 16 cases, included more good results; and in a series of 18 cases in which arthroplasties were performed during the years 1926 and 1927 there was only 1 failure.

The 111 arthroplasties were performed on 101 patients. One case had 3 arthroplasties, 2 had two operations on one knee, and 6 had both knees mobilized. Campbell estimated that the pathological process in a large majority of the cases was probably of gonorrheal origin. Trauma without infection was found to be a negligible

factor in the etiology of ankylosis. Campbell classified his cases into groups, depending upon the factors influencing the outcome.

Of the 87 cases in which arthroplasties had been performed since the first group of 24 cases was reported, 50 patients had ankylosis of one knee in the position of extension or slight flexion. Thirty-four results were successful, 8 were failures, 4 were unknown, and 4 were too recent to report.

In a series of 8 cases of ankylosis in malposition 3 good results were obtained. The remaining 5 cases were failures. Campbell would now perform a two-stage operation in such cases.

In 9 cases of multiple ankylosis from pyogenic infection, there were 4 successful results; 1, fair, and 2 failures. Two outcomes were unknown. Two of these 9 cases were bilateral.

Six cases, in which there was dense scar bone as the result of an extensive osteomyelitis, were not successful as far as mobilization was concerned, but the patients benefited by the improved position of the limbs. Infection flared up in each case. Campbell considers that arthroplasty is contraindicated in ankylosis of osteomyelitic origin.

Of 10 cases of ankylosis due to a low-grade progressive arthritis involving many joints, only 1 resulted successfully, 2 were improved, and 7 were failures.

Campbell's technique is not based upon the principle of modeling the articular surfaces to conform anatomically to the normal joint-ends; rather, he attempts to establish motion and stability by a mechanical modeling of the articulation. The procedure is modified to meet the conditions of (1) the position in which the joint is ankylosed, and (2) the distribution of the ankylosis.

In a case of complete bony fusion of the patella, femur, and tibia in extension, Campbell's technique is as follows: The skin incision begins from 4 to 6 inches above the knee at the outer border of the quadriceps tendon, extends downward, with a slight convexity inward, parallel to the median aspect of the quadriceps, and terminates just below the attachment of the patellar tendon to the tibia. The quadriceps tendon is freed from the femur, and the patella is chiseled loose from the femur. If the quadriceps tendon is markedly contracted, it may be lengthened by the Z-plastic method. The bony union between the tibia and the femur is severed. The posterior part of the condyles of the femur is removed, thus obliter-

ating the intercondylar notch. The lower end of the femur is made convex, the larger part of the bone being taken from the posterior surface of the condyles, so that the length of the limb will not be disturbed. The tibial surface is made slightly concave and forms one surface. Sufficient bone must be removed to leave a space of at least ½ inch. The spine of the tibia and the intercondylar notch of the femur are not reproduced. The posterior surface of the patella is removed until only a thin layer remains. It is then covered with a pedunculated flap from the infrapatellar fat pad.

A strip of fascia lata is removed from the opposite thigh, and inserted into the joint in such a way that not only is there a double layer of fascia between the femur and the tibia, but also a layer is present between the quadriceps tendon and the tissues on the anterior surface of the femur. The joint is closed in the routine manner. Moderate traction is applied, and the limb is placed in a Thomas splint.

Fascial flaps have been used with success by Brandstrup,[33] Hessert,[34] Goddu,[35] Ceballos,[36] Bosch Arana,[37] Ingerbrigsten,[38] Brocq,[39] and Durante.[40]

Albee[9] also has devised a technique that pays no regard to following the natural anatomic contours, but which aims to reconstruct the joint-surfaces by a mechanical modeling. He makes a convex wedge-shaped plane surface of the femoral end to fit into a concave wedge-shaped plane surface of the tibia. Weight-bearing forces the apex of the new femoral end so firmly into the tibia that lateral movement is prevented. A rectangular graft of fascia lata and fat taken from the central portion of the outer aspect of the thigh is used for interposition. Albee objects to the use of fascia lata alone, for he believes that the fat being a semifluid substance, when under pressure, flows into the cavities of the joint and fills up all periarticular dead spaces and thus prevents the formation of hematoma. Albee secured excellent results in 10 cases.

Ogilvy[41] and Hörhammer[42] have also been successful in using free fascial and fatty flaps.

The work of Putti in mobilizing the knee-joint surpasses that of any other operator. By 1920, he had developed a technique that was resulting in stable, movable, and painless joints. In 1922, Putti[1] issued a report on 113 arthroplasties, 40 of which were knee cases. While Putti does not cite his results in detail, they were such

as to lead him to make the following statement: "In ankylosis of the lower extremity it is possible to obtain a solid, painless, and movable joint, not subject to fatigue. The knee is one of the joints in which mobilization gives best results to both the patient and the surgeon." In Putti's experience, the knee ranks second among the joints in order of the success of mobilization. Chevallier,[43] in 1927, reported the results of 63 arthroplasties submitted by Putti. In the majority of cases the ankylosis had been the result of war wounds.

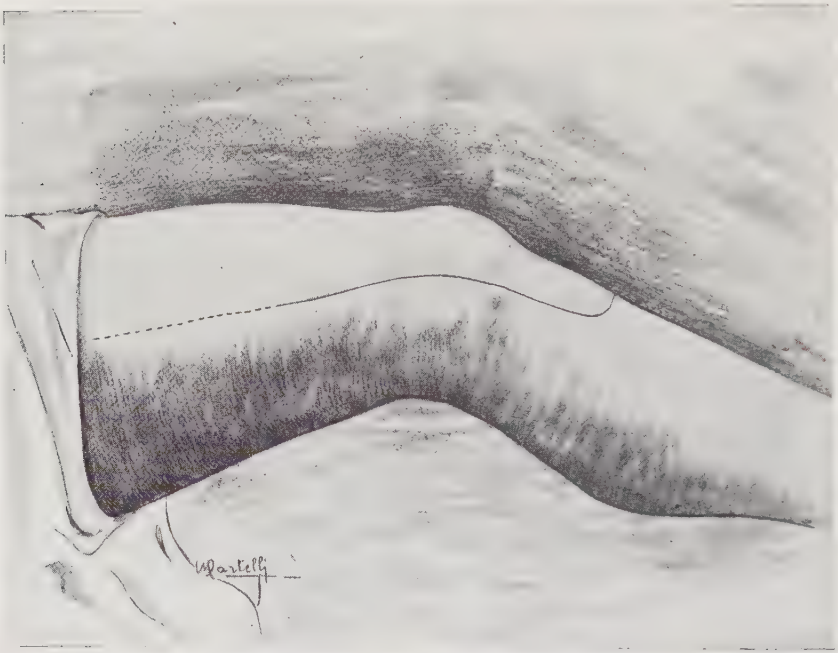

FIG. 57.—Line of Kocher's incision. The dotted line shows the prolongation of the incision, which is necessary to obtain the flap for transplant. (Putti.)

The etiology included acute arthritis, blennorrheal arthritis, chronic polyarthritis, fractures, puerperal arthritis, and typhoid. All cases were very carefully chosen for arthroplasty. Fifty-two good results were obtained, the average mobility of which was 57 degrees. Five mediocre results had flexion of about 25 degrees. Four cases reankylosed. One patient died and 1 result was unknown.

Putti uses free fascial flaps for the interposed material. His technique is as follows: A modification of the Kocher incision is

used, the opening being prolonged below to reach around the tibial tubercle. This allows the skin to be rolled in after the insertion of the patellar tendon has been removed with the tibial tubercle. A piece of bone 4 by 3 cm. wide and 1 cm. deep is removed. Putti believes that the removal of this piece of bone constitutes a weak feature of the Kocher incision, since there is difficulty at times to secure solid union of this bone. Another procedure which may be used instead is that of lengthening the quadriceps tendon through a

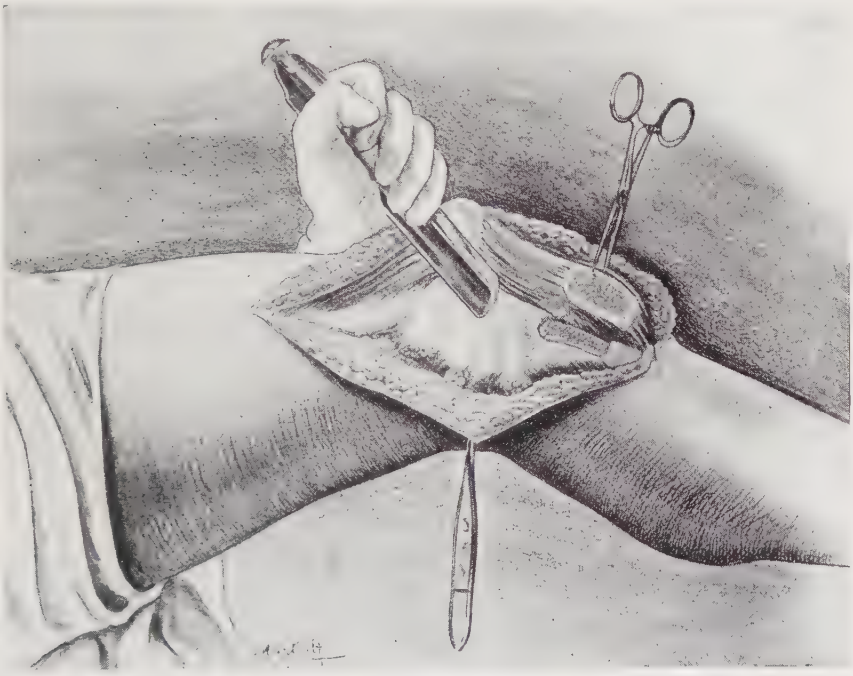

FIG. 58.—Detachment of the tibial tubercle and the arthrolysis. (Putti.)

curved incision. No bone is separated when this method is used and the divided tendon heals quickly. After the insertion of the patellar tendon is freed, the patella is detached from the femur. The skin is retracted to the inside and the joint is exposed.

The ankylosis is freed by chiseling, and the bony lamellæ are broken up by manipulation. The resected surfaces are smoothed by means of files. Any cicatricial mass is removed. The femoral and tibial ends are rounded to approach normal shape, the spine of

the tibia is made sharp, and the intercondyloid groove is deepened. The transverse diameter of the condyles is preserved as much as possible, but the sagittal diameter is decreased. Free fascial flaps, taken from the opposite thigh, are interposed between the resected ends. No patella flaps are used.

The ligamentum patellæ and the tibial tubercle are nailed in place by means of a double-headed nail. The nail is usually removed in about a month. (Figs. 57, 58, 59, 60 and 61.)

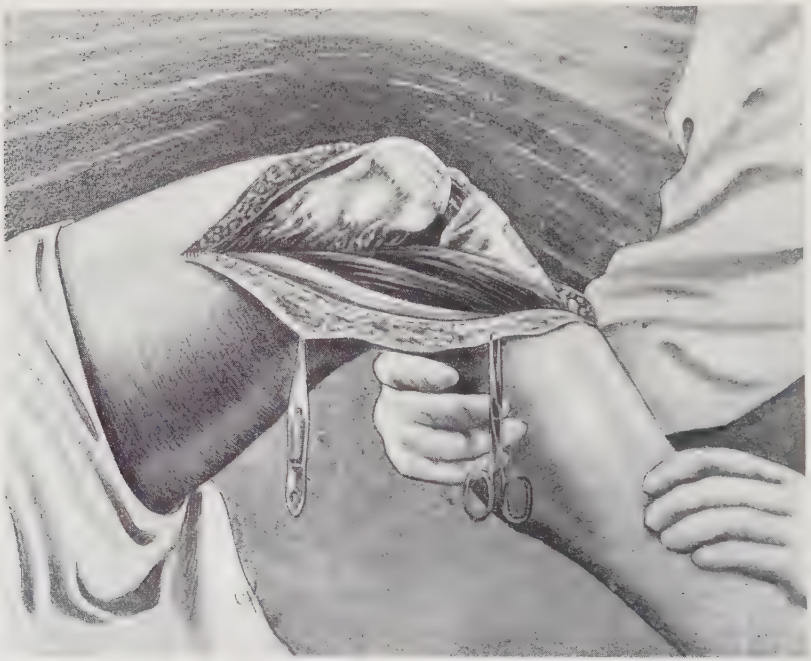

Fig. 59.—Luxation of the joint surfaces. (Putti.)

For fifteen days, the entire leg remains in semiflexion in a gutter splint. Four to 5 kg. traction is applied. After the removal of the stitches, the knee is suspended from an overhead frame equipped with a strap and pulley. The amount of exercise depends upon the patient's ability to stand pain and upon the reaction of the joint. Gravity is used in securing flexion by having the patient sit on the edge of the bed and allow his limb to hang off. In a month, massage, faradism, heat, and mechano-therapy (Bonnet's apparatus) are

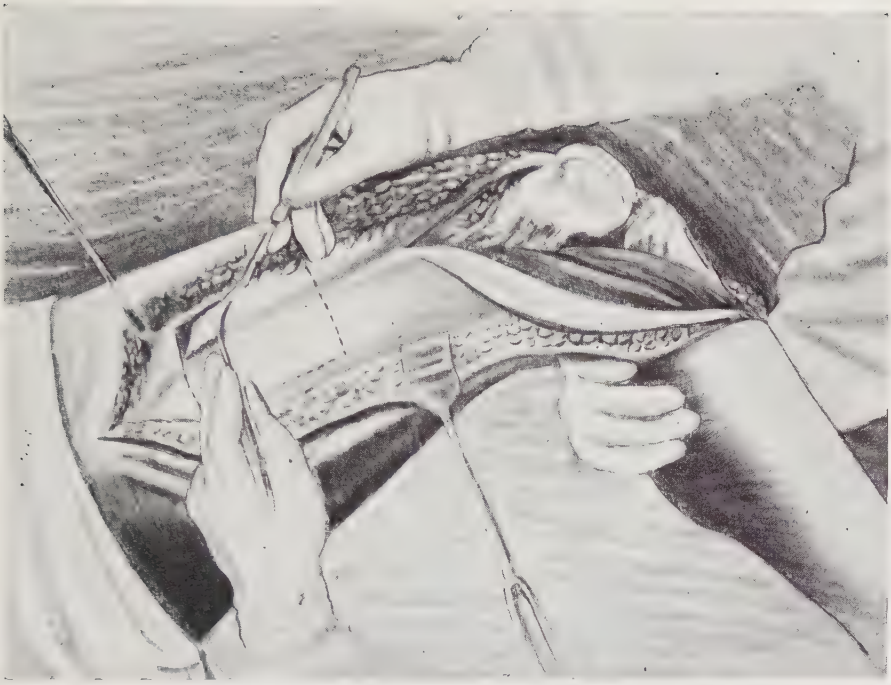

Fig. 60.—Preparation of the fascial flap. (Putti.)

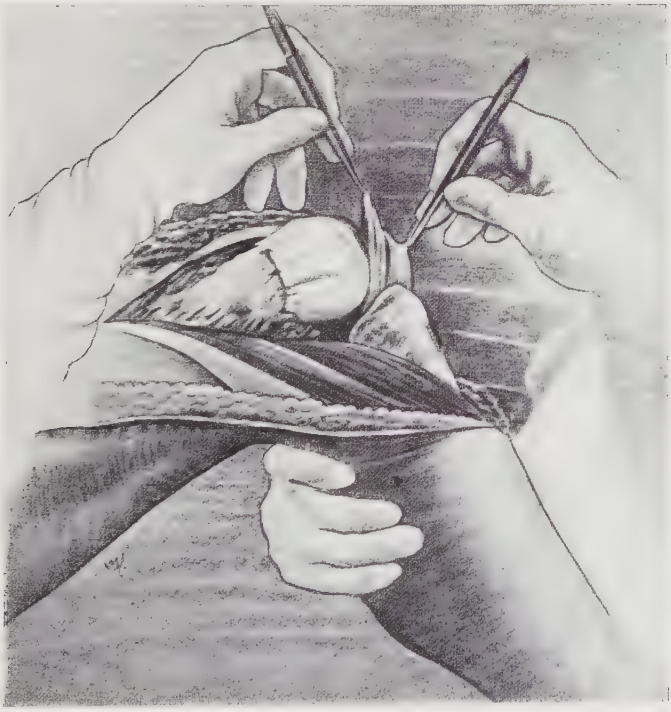

Fig. 61.—Attachment of the flap on the resectioned surfaces. (Putti.)

used. In one and a half months a stiff leg brace is applied. The patient should have good use of his limb in three months.

The following case is one reported by Putti:

Fig. 62.—Case XIII. Before mobilization. (Putti.)

Case XIII.—*History.*—The patient had suffered a suppurative arthritis that had caused wounds to be opened in his knee for five months. A deep cicatrix resulted. Bony ankylosis occurred between the femur and the tibia and between the femur and the patella, with periarticular ossification. (Figs. 62 and 63.)

Treatment.—Putti used his regular technique in doing an arthroplasty.

Result.—One month after intervention there was 40 degrees flexion and complete extension, without pain.

In five months the patient could walk long distances, and he had complete extension and flexion to 110 degrees.

In seven months the flexion was 85 degrees, and there was some lateral movement. The leg, however, was serviceable.

FIG. 63.—Case XIII. Before mobilization. (Putti.)

Fourteen months after operation the patient returned to the hospital because of severe pain in the knee. The joint was flexed in the position of semiflexion and could not be extended. After traction and hot-air applications the joint improved, and the patient was able to walk again.

Twenty-seven months after the first operation he could flex his knee to an angle of 85 degrees and had a movable patella and no lateral mobility. (Figs. 64, 65, 66, 67 and 68.)

FIG. 64.—Case XIII. Roentgen film taken twenty-seven months after arthroplasty. (Putti)

FIG. 65.—Case XIII. Roentgen film take twenty-seven months after arthroplasty. (Putti.)

FIG. 66.—Case XIII. Showing weight-bearing and active extension after mobilization. (Putti.)

FIG. 67.—Case XIII. Showing weight-bearing and active extension after mobilization. (Putti.)

Leriche and Santy,[44] Mocquot.[45] and Lenormant[46] have used Putti's method in knee arthroplasties. Leriche and Santy did not secure a good result; the joint was wabbly and the quadriceps limited in activity. Mocquot's case was a knee ankylosed in flexion as the result of pneumococcic infection. Following opera-

Fig. 68.—Case XIII. 85 degrees flexion after mobilization. (Putti.)

tion, the patient had flexion to a right angle, and the joint was solid although there was slight lateral movement. Lenormant's case was a knee ankylosed as the result of a gonorrheal infection. Due to a secondary infection resulting from a hematoma, the flap was extruded, and ankylosis recurred.

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ARTHROPLASTY OF THE HIP-JOINT.

Within the last ten years arthroplasty of the hip-joint has made definite strides forward. Although, with few exceptions, the num-

ber of cases reported by any one surgeon has been too small to form a basis upon which to estimate the proper value of the different methods used in mobilizing this joint, still the attempts made have been of real worth. A good foundation for future work has been laid, particularly through the efforts of Baer[1] and Campbell.[2] Undoubtedly, as we learn to select the types of cases suitable for arthroplasty, and to determine the favorable time for mobilization, the percentage of good results will increase. Eventually, arthroplasty of the hip will take its place beside mobilization of the elbow and the knee as a recognized surgical procedure.

Requisites of a Good Arthroplasty.—To be considered successful an arthroplasty of the hip must restore to the joint at least 25 degrees voluntary flexion. The new joint must be stable in weight-bearing without the need of a support. The hip must be free from pain. When motion of 25 degrees is possible in the hip the gait tends to be natural and there is little discomfort when sitting. This motion, however, is of value only when the joint is stable in weight-bearing. Hence the importance of careful remodeling of the joint to assure stability cannot be overemphasized.

Indications and Contraindications.—Arthroplasty should be used with discrimination in cases of ankylosed hip-joints. Caution is particularly necessary in single ankylosis. A hip stiff in good functional position, that is, 5 to 10 degrees abduction, 10 degrees flexion and slight external rotation, is a serviceable member, since compensatory hypermobility of the lumbar spine makes walking possible with only a very slight limp. (Fig. 69.) It is possible to make any hip functional to this degree by taking care that the joint becomes ankylosed in good position, or by correcting malposition if it has been allowed to occur. In spite of the knowledge that the functional position will afford the greatest advantage, practically all patients with ankylosed hips come to our clinics with the joint in the position of deformity, that is, flexion and adduction. (Fig. 70.) Correction of this deformity will improve function.

Although the hip is serviceable when stiff in good position, the gait is interfered with, sitting and stooping cause discomfort, and going up and down stairs is difficult. It is on account of these inconveniences that the majority of patients seek relief. Some patients, whose occupation depends upon a mobile joint, have a more urgent need for motion in the hip.

In bilateral ankylosis the decision to mobilize is more easily made than in single ankylosis, because the disability is so great that relief is urgent. Arthroplasty should be considered on one side at least. This treatment is advisable in spite of the fact that the prognosis

FIG. 69.—Ankylosis of the hip. Note proper position, *i. e.* abduction 10 degrees flexion 10 degrees and slight external rotation.

in bilateral cases is more uncertain than in single cases, owing to the increased operative risk due to the presence of associated medical problems.

FIG. 70.—Ankylosis of the hip with deformity

Among the general factors to be considered in arthroplasty of the hip are: Primarily the patient's need for motion; the type of ankylosis; the origin of the stiffness; the eradication of an infectious

process; the condition of the bone, musculature, and skin; and the age and social circumstances of the patient. (See general discussion on Indications and Contraindications, p. 49.) If the ankylosis is a massive osseous one with a large area of destruction and new-bone formation, it is usually better to place the hip in good functional position than to attempt arthroplasty, because of the operative difficulty and the associated tissue damage.

Prognosis.—The hip lends itself well to arthroplastic measures. Baer,[1] in his analysis of 100 arthroplasties of the hip, has furnished interesting details on the results of arthroplasty in different pathological conditions. In bony ankylosis resulting from fracture of the femoral head and acetabulum, arthroplasty gives excellent results because the periarticular structures are normal. This has been the experience of most operators. In cases of gonorrheal origin a stable, painless joint may be expected as the outcome of arthroplasty. One should not attempt operation until one and a half to two years after the disease is quiescent.

The outcome of arthroplasty in cases of septic origin due to the staphylococcus, the streptococcus, the influenza bacillus, or the pneumococcus depends largely upon the selection of the case. Provided these cases are selected with judgment, the result will be favorable. Not only the local pathology, but the general condition of the patient must be carefully considered. A fat person who has a long history of suppuration is not a favorable subject. If a large area of scar tissue is present it should be removed by a preliminary operation. Two or three years must have elapsed from the subsidence of the disease, before arthroplasty is contemplated, since a quiescent infection may be lighted up by interference.

Tuberculous cases are considered by the majority of operators to be unsuitable for arthroplasty, owing to the risk of stirring up dormant pockets of infection. The experience of Baer,[1] who has performed operations in 6 cases of tuberculous origin and obtained good results in all, would lead one to question if arthroplasty is not justified in certain tuberculous cases. Of prime importance is the selection of the case. The patient must be in excellent health, and all signs of the disease must have been quiescent for years.

Bilateral cases offer a more difficult problem than a single ankylosis, and the outcome is more dubious. If the case is one of infectious origin the process is usually widely distributed, and hence,

there is the possibility of stirring up infection. The resistance of the patient is usually lowered by his prolonged inactivity. Practically all cases are seen in the position of deformity. Obviously, the after-treatment is hampered by ankylosis of the other hip-joint. The patient with bilateral ankylosis of the hip is materially benefited by the restoration of motion to one hip and the correction of deformity in the other joint.

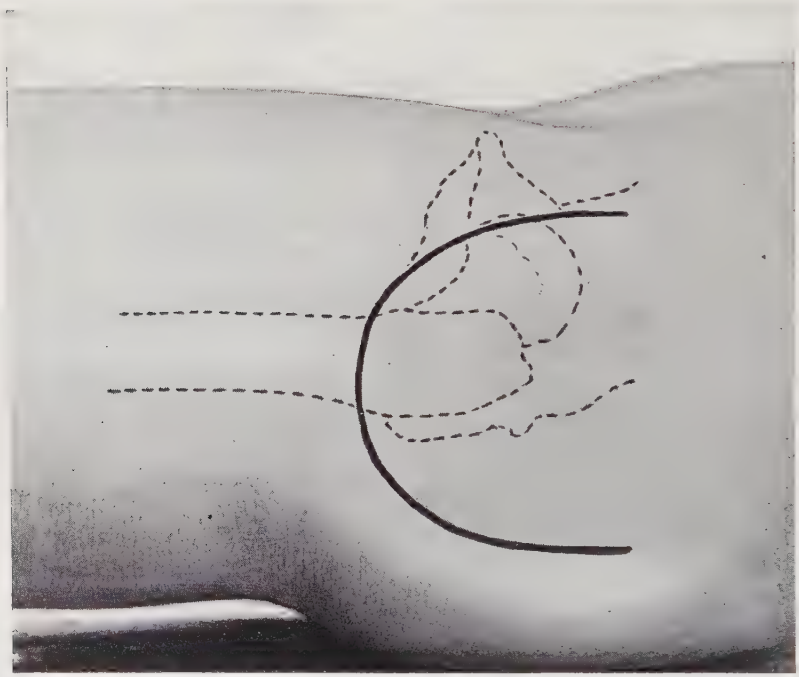

FIG. 71.—Arthroplasty-hip technique. U-shaped skin incision. (MacAusland.)

Operative Technique (Writers').—In our experience we have made but few attempts to mobilize the hip-joint. Recently, we have developed the following technique, which is giving consistently good results, but we believe that much yet remains to be done in this field.

A very careful two-day preparation is given to the operative area extending from the rib-line to below the knee.

The skin incision, U in shape, begins at the antero-superior spine, extends downward in a horizontal plane to about 2 inches below

the level of the trochanter, then curves over the femur about 3 to 4 inches below the trochanter, and terminates at a point opposite the point of origin. (Fig. 71.) The skin flap with considerable fatty tissue attached is elevated, raised to its base-line, and retracted.

A similar incision is made through the fascia external to the sartorius. At a point about 3 inches below the trochanter the incision reaches the femur. (Fig. 72.)

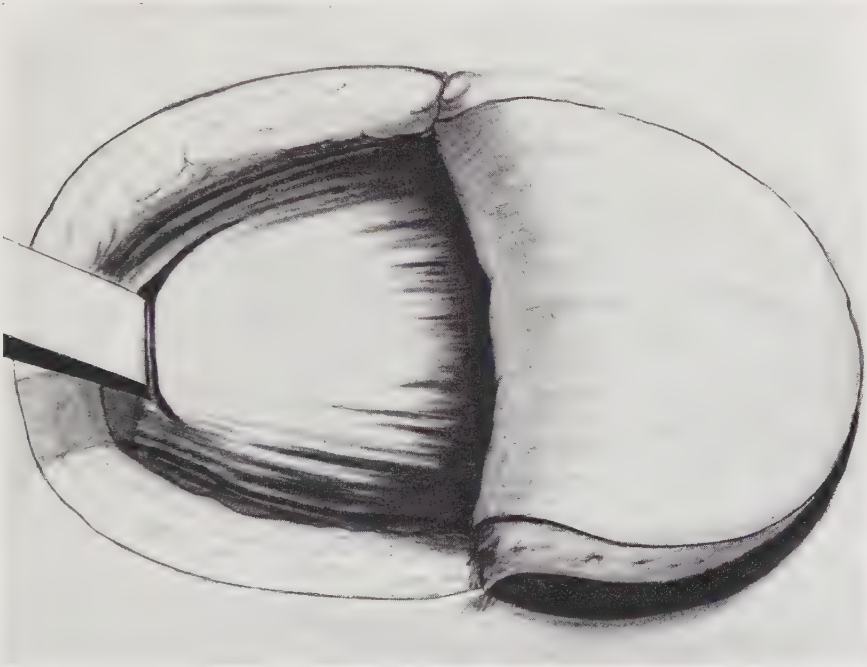

FIG. 72.—Arthroplasty-hip technique. Line of fascia incision preparatory to the removal of the great trochanter. (MacAusland.)

The periosteum on the femur is separated downward for a distance of $\frac{1}{2}$ inch, and upward as far as the base of the trochanter. By means of a 2-inch osteotome, the entire trochanter is removed and retracted upward, the operator taking all the muscle attachments with the flap.

An incision is then made through the capsule, beginning on the ilium, passing parallel to and in the center of the femoral neck, and extending as far as the base of the detached trochanter. (Fig. 73.) The capsule, at its attachment to the femoral neck, is separated on

both sides for a distance of $1\frac{1}{2}$ inches and retracted. By means of a blunt dissector the capsule is freed from about the neck as far as possible.

A study of the union between the femoral head and the acetabulum is then made. The operator, using a curved chisel, and covering a small space at a time, frees the femur from the cavity. Care should be taken to follow the outline of the acetabulum—a step that

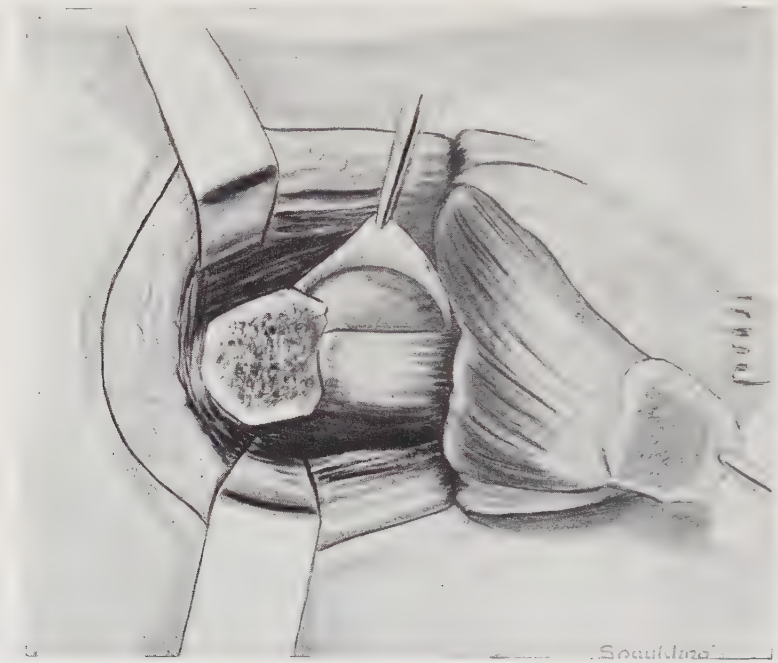

FIG. 73.—Arthroplasty-hip technique. Incision through capsule parallel to and in center of femoral neck. (MacAusland.)

is difficult because the head is usually atrophied. (Fig. 74.) The femoral head is then dislocated. The acetabulum is thoroughly reamed out, and the head carefully rounded by means of the Murphy male and female rasps. (Figs. 75 and 76.) Great care must be taken to remove all spicules of bone.

A piece of free fascia lata, taken from the outer side of the opposite thigh, is sewed first around the neck of the femur with interrupted sutures, and then folded into the acetabulum, so that there is a

double layer of fascia in the joint space. A purse string is tied tightly around the femoral head. (Fig. 77.)

The head is reduced. (Fig. 78.) The old capsule is brought into place, and its edges are sewed to each other, and insofar as possible to its old attachments. We believe that the suturing of the capsule adds to stability by preventing dislocation or a wabbly joint.

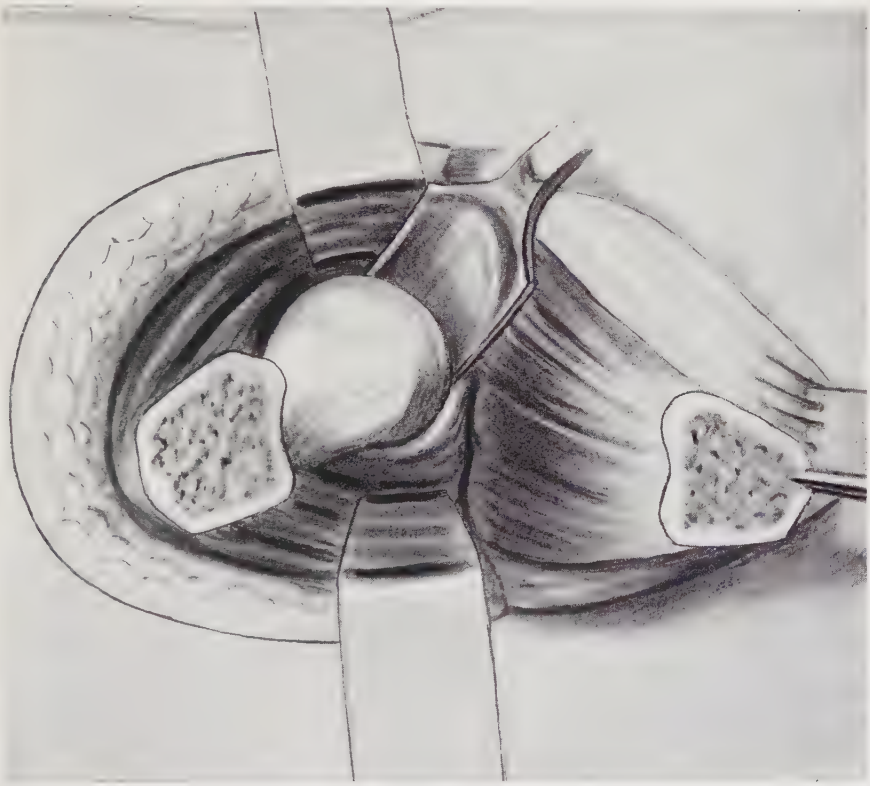

Fig. 74.—Arthroplasty-hip technique. Separation of the femur from the acetabulum. (MacAusland.)

The trochanter is drawn down to its old position and held in place by suturing it to the periosteum that was previously elevated. The skin incision is closed. A plaster bandage extending from the nipple line to the toe is applied with the leg in 10 degrees abduction and complete extension, and with slight pressure over the trochanter.

After-Treatment.—Upon the removal of the plaster bandage, usually about a week or ten days after operation, the leg is placed in a ring caliper, and traction varying from 8 to 15 pounds is applied with the leg in extension and abduction. Traction is kept on continually for a period of two to six weeks. The traction appara-

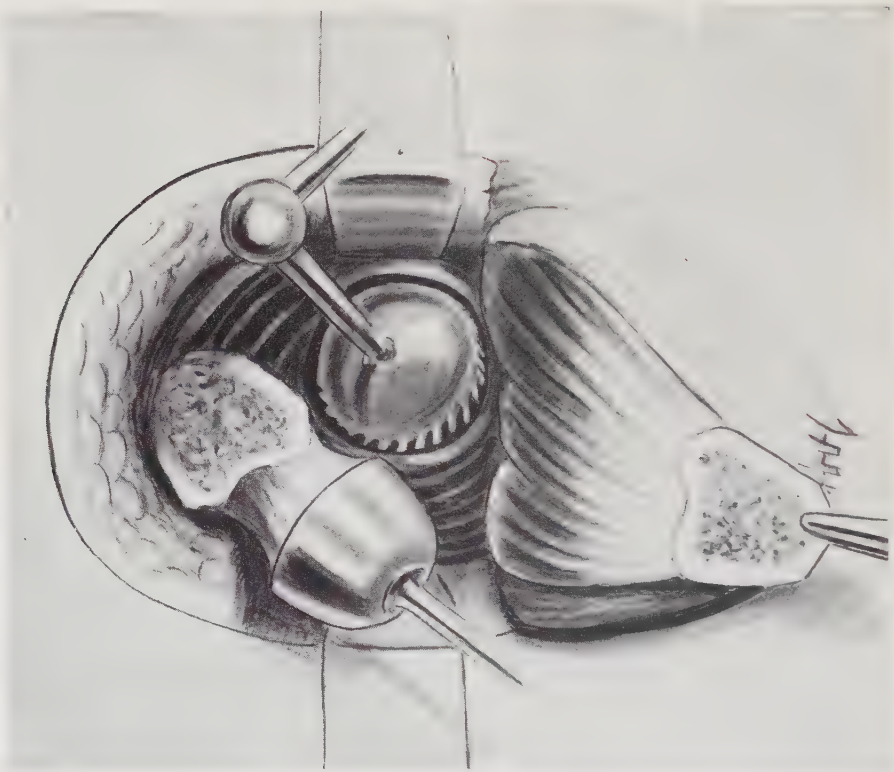

FIG. 75.—Arthroplasty-hip technique. Reaming out of acetabulum and rounding of head with Murphy male and female rasps. (MacAusland.)

tus is equipped with a line and pulley arrangement, by means of which the patient is able to guide the early passive movements. (See p. 46 for description of apparatus.) Such an adjustment gives the patient confidence in moving the limb, and voluntary spasm is not so great as when an operator guides the movements.

Active motion is begun as soon as movement can be carried out without pain. To gain control of his thigh muscles, the patient is

urged to contract them frequently. Swimming is one of the best means of securing muscle activity and developing the tenacity of the ligaments.

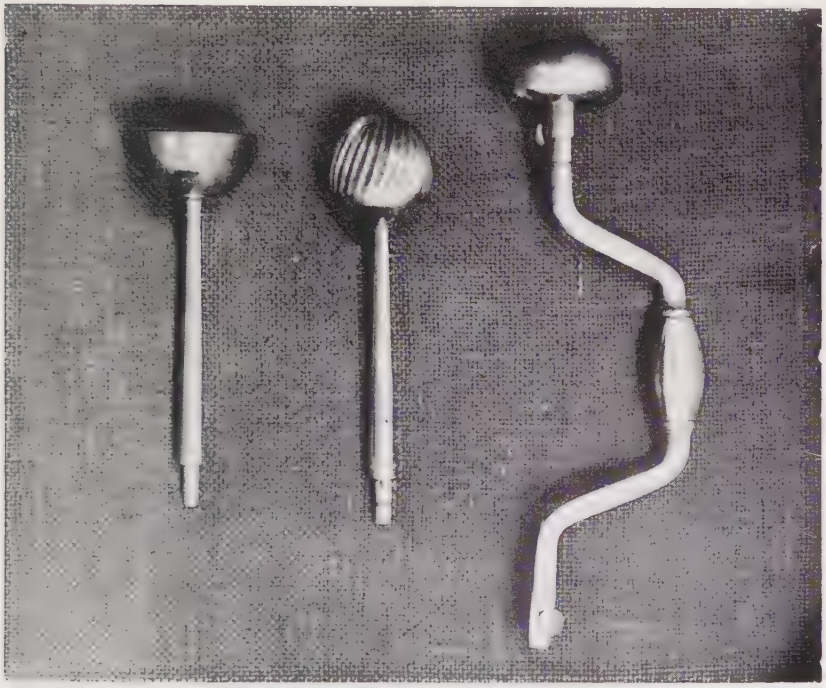

FIG. 76.—Murphy instruments.

Weight-bearing is begun when the ligamentous structures approach normal, usually in about eight weeks. The increase in weight-bearing is influenced by the clinical manifestations of pain, sensitiveness, and soreness, and to a certain extent by the density of the head and neck, as determined by Roentgen films.

CASES (WRITERS').

CASE XIV.—O. P., aged twenty-four years.

History.—This patient suffered severe pain in both heels, the cause of which was probably of Neisserian origin. For several months he obtained temporary relief from strapping. The pain finally returned in the heels and also appeared in both hips. The pains were severe and radiated to the knees and ankles. These joints became swollen. For several weeks a physician treated the patient for

rheumatism. After six weeks of pain in hips, knees, and ankles the patient entered our clinic.

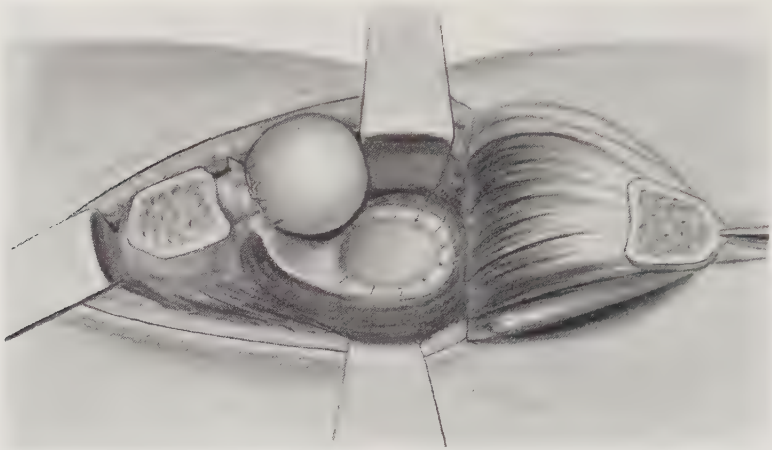

FIG. 77.—Arthroplasty-hip technique. Double layer of fascia in place. (MacAusland.)

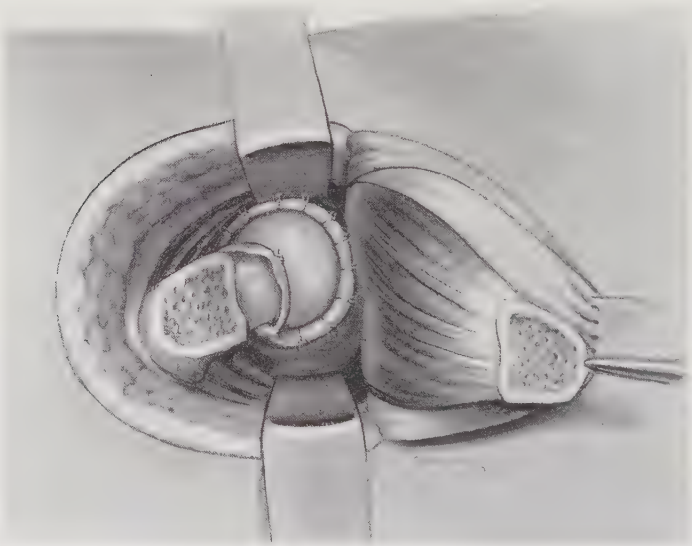

FIG. 78.—Arthroplasty-hip technique. Femoral head reduced. (MacAusland.)

Treatment.—For ten weeks traction was kept on the legs. The patient was relieved to the extent of being able to walk. A plaster spica was applied to the left hip, and worn for five months. As the

right leg then began to pain, the left spica was removed and a double plaster applied, extending just below the knees. This spica was worn for six months, and during that time the patient was in bed. Upon its removal both knees and both hips were stiff. (Figs. 79 and 80.)

FIG. 79.—Case XIV. O. P. Roentgen film showing ankylosis of right hip before arthroplasty. (MacAusland.)

For two and a half years no special treatment was carried out. During this time the patient was able to bear weight, but suffered considerable disability.

May 1, 1920: An arthroplasty of the right hip was performed.

May 17, 1920: The plaster bandage was removed and passive movements were begun.

FIG. 80.—Case XIV. O. P. Roentgen film showing ankylosis of left hip before arthroplasty. (MacAusland.)

June 10, 1920: The patient was walking with crutches.

Result.—January 13, 1923: Two years and seven months after operation there was flexion of 40 degrees and motion in adduction and abduction in an arc of 15 to 20 degrees. (Figs. 81, 82 and 83.)

FIG. 81.—Case XIV. O. P. Roentgen film showing right hip two and a half years after arthroplasty. (MacAusland.)

FIG. 82

FIGS. 82 and 83.—Case XIV. O. P. Motion in right hip two and a half years after arthroplasty. (Patient has about twice this arc of motion, but is handicapped in further flexion by double ankylosis of the knee.) (MacAusland.)

FIG. 83

Case XV.—O. P., aged twenty-four years.

History.—The history of this case is reported under Case XIV.

Treatment.—November 2, 1920: Seven months after operation on the right hip an arthroplasty of the left hip was performed.

November 27, 1920: The plaster bandage was removed.

December 6, 1920: Passive motions were started.

January 4, 1921: The patient was walking with crutches.

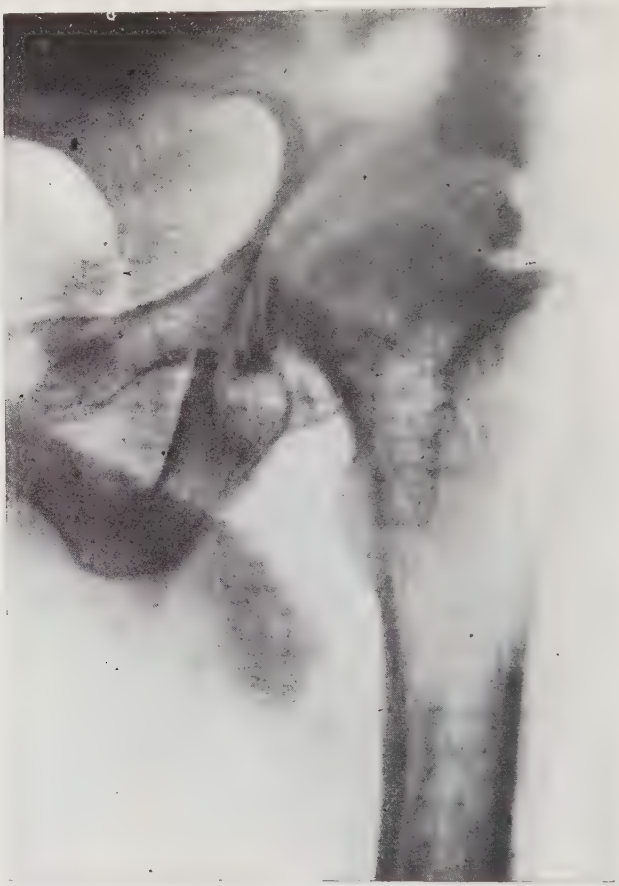

Fig. 84.—Case XV. O. P. Roentgen film of left hip two years after arthroplasty (MacAusland.)

Result.—January 20, 1923: Two years and two months after arthroplasty the patient was walking without pain. The left hip had 40 degrees flexion and good abduction and adduction. The functional result was good. The patient was handicapped by double ankylosis of the knees. (Figs. 84, 85, 86, 87, 88 and 89.)

FIG. 85

FIG. 86

FIGS. 85 and 86.—Case XV. O. P. Motion in left hip two years after arthroplasty. (Patient has about twice this arc of motion, but is handicapped in further flexion by double ankylosis of the knee. (MacAusland.)

FIG. 86

FIG. 87

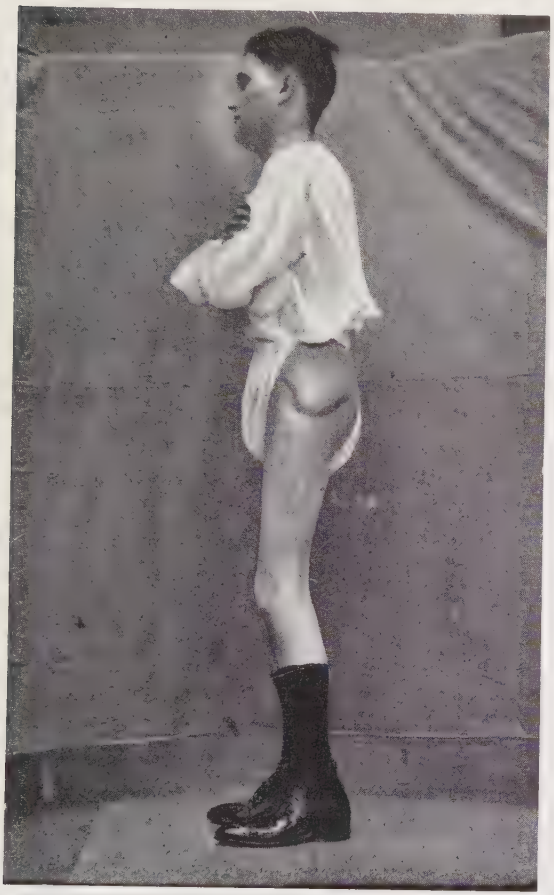

FIG. 89

FIGS. 87, 88 and 89.—Cases XIV and XV. O. P. Standing positions after arthroplasty of both hips. (MacAusland.)

CASE XVI.—A. M., aged twenty-four years.

History.—At the age of sixteen years this patient injured his spine while skating. For sometime afterward he was treated for pain in the spine and hip, but obtained no relief. When, finally, both hips became ankylosed he was treated in casts and by operation, but without success.

Physical Examination.—We first saw the patient eight years after the injury. He walked with crutches in the attitude assumed when the legs and back are stiff. Both hips were stiff in deformity of 35 degrees flexion. There was slight adduction of both legs.

Treatment.—April 18, 1923: An arthroplasty was performed on the left hip according to the regular technique.

May 9, 1923: The wound had healed by first intention. The patient was beginning to get muscle control.

May 14, 1923: Patient had about 25 to 30 degrees voluntary motion without pain.

June 9, 1923: The hip had 45 degrees flexion and abduction to 20 degrees.

FIG. 90.—Case XVI. A. M. Roentgen film of left hip, one year and two months after arthroplasty. (MacAusland.)

Result.—June 3, 1924: One year and two months after arthroplasty the hip had 45 degrees flexion and 10 degrees abduction and adduction. The hip was held in 10 degrees permanent flexion and in slight rotation. There was pain on extremes of motion. (Fig. 90.)

CASE XVII.—R. B., aged sixteen years.

History.—When this boy was fourteen years of age he suffered a direct injury to the left hip while playing football. The hip was

kept in a plaster bandage for five months, and then a T-splint was applied. There was no pain, but the boy limped considerably.

Physical Examination.—The condition had been of two years' duration when he first came to us for treatment. He walked with the left leg everted and limped and dipped to the side. There was 25 degrees outward rotation. The left calf was atrophied one-half and the left thigh one-quarter. The left leg was $1\frac{1}{2}$ inches short. There was about 5 to 8 degrees motion in everted flexion. The trochanter was 2 inches above Nélaton's line.

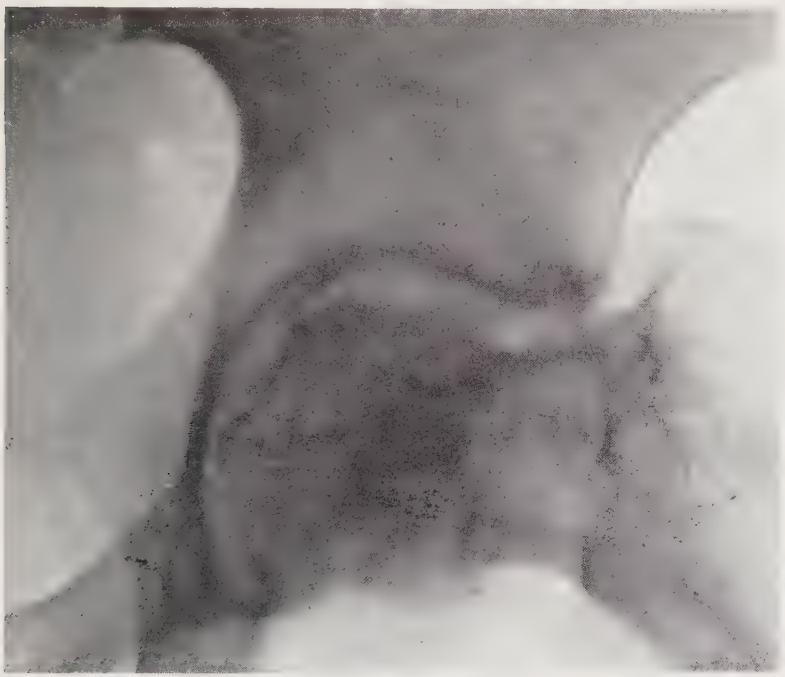

FIG. 91.—Case XVII. R. B. Roentgen film showing union between femoral neck and the acetabular rim, and between the femoral head and the acetabulum.

Treatment.—April 15, 1926: An attempt was made to reduce the femoral neck, which was displaced anteriorly and upward. The line of separation between the femoral neck and the head was exposed. The hip was forcibly manipulated into as much abduction and internal rotation as possible, and a plaster bandage was applied with the hip in this position.

June 26, 1926: The hip was in perfect position. From *June, 1926*, until *January, 1927*, the patient followed a carefully regulated system of exercise, of which swimming formed the major part. When motion did not seem to be returning, two manipulations were

done, one on *April 8, 1927,* and the other on *June 27, 1927.* Motion was not obtained.

December 31, 1927: Examination showed that the hip had no motion. The limb was in the position of abduction, which was causing a curvature of the spine—a serious condition. In view of the certainty of the progression of this curve, operation was imperative. A Roentgen film showed a bony ankylosis between the head and the acetabulum, and between the femoral neck and the acetabular rim. (Fig. 91.)

Fig. 92.—Case XVII. R. B. Roentgen film showing line of the arthroplasty in the upper femoral neck. (MacAusland.)

April 3, 1928: An arthroplasty was performed. Owing to the extensive cicatricial tissue due to the epiphyseal separation and to the long time it remained uncorrected, the whole region was uncovered with considerable difficulty. True union was found between the neck of the femur and the outer margin of the acetabulum. An attempt was made to dislocate the head, but this was impossible on account of the adhesions and fibrous tissue. The neck of the femur was cut close to the head, dislocated, and rounded. A free transplant of fascia was placed around it. The head of the femur was reamed out, and the newly-formed neck placed in the acetabulum. The long end of the fascia was sutured to the anterior capsule.

April 21, 1928: Motion was started in the hip.

May 25, 1928: There was motion in flexion of 45 to 50 degrees and abduction of 10 degrees. The shortening amounted to only 1 inch and was to be compensated by a lift on the shoe.

Result.—June 13, 1928: The hip was in splendid condition, and the back was straight. The hip had about 55 degrees motion in flexion and excellent rotation. A Roentgen film (Fig. 92) showed the head fixed in the acetabulum over a sufficient area to ensure no slipping.

July 27, 1928: The patient was making definite progress. He could use the limb better and could reach his foot with both hands for the first time in several years. (Fig. 93.)

November 30, 1928: Hip remains stable and motions continue to increase. Prognosis is excellent.

FIG. 93.—Case XVII. R. B. Showing flexion after arthroplasty. (MacAusland.)

CASE XVIII.—J. P., aged twenty-one years.

History.—This patient had been troubled for the past six years by lameness in the right hip. The condition had followed an injury to the hip.

Physical Examination.—September 27, 1928: The right hip had a marked flexion-adduction deformity. Motion in flexion of 25

degrees was possible with no rotations. The Roentgen film showed marked flattening of the head of the right femur and some deformity of the acetabulum, apparently due to erosion of the upper border (Fig. 94).

Treatment.—October 10, 1928: An arthroplasty was performed on the right hip.

Result.—December 13, 1928: A Roentgen film showed a clear joint space and good position of the head of the femur (Fig. 95).

FIG. 94.—Case XVIII. J. P. Roentgen film before arthroplasty, showing flattening of the head and deformity of the acetabulum. (MacAusland.)

January 3, 1929: The hip had 3 to 5 degrees of abduction and about 10 degrees of flexion.

Comment.—As only four months have elapsed since the operation, a final result cannot be reported. The Roentgen film and the steadily increasing motion warrant a favorable prognosis. This case illustrates the fact that an adduction deformity is not a contra-indication to an arthroplasty.

Résumé of Literature.—Hoffa's[3] statistics, published in 1906, included 5 early arthroplasties of the hip, 3 of which had been performed by Rochet and 2 by Nélaton. Muscle flaps were used in these cases. One of Rochet's cases had good function in extension and flexion of 45 degrees eight months after operation. His second case had a mobility of 40 degrees antero-posteriorly one year after arthroplasty. The third case had an immediate good result, but two and a half years later, only by taking short steps could the patient walk well. One of Nélaton's cases had good function five years after operation. The result in his other case was poor.

FIG. 95.—Case XVIII. J. P. Roentgen film taken two months after arthroplasty, showing joint space. (MacAusland.)

Hoffa reported 2 personal cases in which pedicled flaps of fatty tissue were used for interposition. Following operation, one patient had active abduction and slight rotation, and flexion and extension were possible in swinging movements. The gait with the use of support was fairly good. The other patient could use the hip considerably, but abduction and flexion were limited.

Cases in which flaps of muscle were inserted were reported by other operators. Stein,[4] in 1907, in performing an operation in Bier's Clinic for a case of double ankylosis, used a layer of the sartorius muscle. Five months after operation flexion and extension were 30 per cent normal, and abduction and adduction were 10 per cent normal. Ahrens[5] used a flap taken from the gluteus maximus. The patient made a good recovery, and in four months could walk without a cane. Vulpius[6] used fatty flaps reinforced with a thin layer of the gluteus in 5 cases, with good results. Dreyer[7] used a muscle flap in 1 case. Two months after operation there was active flexion to 45 degrees.

Meyer[8] reported an arthroplasty for an ankylosed hip of spondylitic origin, which was flexed on the pelvis at 150 degrees and adducted at 75 degrees. A flap of fatty tissue with a thin layer of muscle was inserted. Two years after operation the patient could extend his leg normally, abduct it to 45 degrees, adduct it to 30 degrees, and flex it to 60 degrees. She had no pain and walked well without the use of a cane.

It was in the hip-joint that Murphy[9] used his pedicled fascia-flap method with most success. Up to 1913 he had reported 20 arthroplasties of the hip, obtaining in several cases a good range of motion and a stability that allowed walking without the use of a support. (Comment: The writers question if these hips were always stable. The cases which we had the opportunity to examine did not have the degree of stability that we recognize as a requisite to a successful arthroplasty.)

Murphy's technique was as follows: One of three incisions was used, depending upon the type of case. One incision was U-shaped, beginning $1\frac{1}{2}$ inches above the trochanter and 1 inch behind it, extending down 2 inches below the trochanter, and passing under and in front of it up to a point opposite the commencement. The second incision was along the ilio-trochanteric line, beginning 1 inch below and in front of the trochanter, and extending upward for about 5 inches in a straight line with the antero-superior spine of the ilium. The third incision was a modification of the second and was curved and convexed backward behind the trochanter.

The trochanter was freed by a chain-saw and retracted upward with its attached muscles. The ankylosed head of the femur was

severed from the ilium as near the anatomic line as possible. The head was fractured out and the acetabular cavity fashioned by means of a special burr. A cup-shaped end-mill was used to model the femoral head.

A pedicled flap of fascia lata and subcutaneous fatty tissue was inserted behind the head and neck of the femur. The edge of the flap was sutured to the acetabular margin and to the capsular ligament with phospho-bronze wire. The head was replaced. The trochanter was nailed in place. The fascia was approximated with chromic catgut, and the skin sutured with silkworm or horsehair. No drainage was used.

The operative field was dusted with bismuth subiodide powder, and the wound sealed with gauze saturated with collodion. A pad of plain sterile gauze moistened with 95 per cent alcohol and 61 per cent phenol was placed over the hip, extending 4 or 5 inches beyond the line of incision. A Rainey travois splint and Buck's extension with 20 to 25 pounds' weight were applied. Both legs were dressed in an abducted position. Passive motion was instituted in seven to ten days.

The Murphy method was attempted by several operators, including Pettis,[10] Torrey,[11] Gibbey,[12] Rovsing,[13] Ceballos,[14] Prando,[15] Thomson,[16] Burlew,[17] Addison,[18] Corner,[19] and Bull.[20] Of this group, Burlew secured satisfactory results in 4 cases, Bull in 2 cases, and Gibbey in 1 case. The reports of Pettis and Corner are incomplete. Torrey's case had good walking ability eleven months after operation, and indications for further improvement were favorable. Addison's case secured free flexion, and the patient could walk well. Thomson's case re-ankylosed.

Grange[21] reported a case of arthroplasty of the hip, in which he made a curved incision between the crest of the ilium and the great trochanter, divided the femur at its neck, and sutured over the raw end a flap from the gluteus medius. A loose flap of fat taken from the buttock was placed in the cup in the head of the femur. Within two months the patient could flex his hip to a right angle.

Perthes[22] used a modification of the Murphy method in a hip ankylosed in the position of adduction. Two pedicled fat and fascial flaps were interposed. In spite of the other hip and both knees being ankylosed, and in spite of paralysis of the sciatic nerve, walking was possible with two canes.

The method involving the use of the pedicled fascia-fat transplant has been superseded for the most part by the use of free fascial flaps. Other modern methods that are giving good results are Baer's membrane method and Lexer's arthroplasty in which flaps of fatty tissue are used.

Lexer,[23] in 1925, reported having performed 29 arthroplasties of the hip for ankylosed conditions. Seventeen good results were obtained; 6 cases were failures; and 6 results were questionable. Lexer uses a curved incision, separates the femoral head from the acetabulum, molds the joint-ends, and interposes a fatty-tissue flap, which is fixed on the femoral end. If it is not possible to construct the femoral end so that the head and the neck are at an angle to the acetabulum, Lexer builds a bony bridge on the upper rim of the acetabulum to prevent luxation.

Krüger[24] performed Lexer's operation, using the bone-block, in a case of ankylosis of tuberculous origin. He obtained an excellent result.

The operators who have made use of the free fascial flap most extensively are Payr,[25] Putti,[26] and Campbell.[2] Odelberg,[27] Monjardino,[28] Durante,[29] Hallopeau,[30] Osgood,[31] Truslow,[32] and Dreyer[33] have each reported a few arthroplasties of this nature. Odelberg did not secure satisfactory results. Monjardino obtained an excellent result in 1 case. Durante's outcome was splendid as to flexion and extension, but rotation and abduction were limited. Hallopeau secured a good weight-bearing joint. Osgood's result was good. Truslow's case, one of tuberculous origin with marked deformity, resulted very satisfactorily. Dreyer's case had flexion of about 45 degrees three months after operation.

In 1921 Hohlbaum[25] issued a report on the results of 20 arthroplasties of the hip that had been performed in Payr's Clinic. In 6 cases the results were good; 6 cases re-ankylosed; 2 patients died; 1 case was too recent to report. The very good results were considered as having stability, active flexibility of at least 90 degrees, and no pain. The good results were judged upon a similar degree of motion, but slight stability and occasional pain might be present.

The latest report we find of Putti's[26] work in hip cases, published in 1921, includes a series of 17 cases in which arthroplasties had been performed since 1911. Of 4 cases of arthroplasty for bilateral

ankylosis, in which operation was performed upon both sides at the patient's request, only 1 result was successful, 1 was moderately satisfactory, and 2 were failures. Putti believes that bilateral cases should be treated on one side only.

Cesarano[33] used Putti's method in 5 cases. After operation walking without support was possible in 3 cases. The other 2 results were indefinite, the report simply stating that a sufficient range of movement and a movable and painless hip were obtained.

Campbell[2] has had the most experience in arthroplasty of the hip-joint in which free grafts of fascia were used. In 1927 he presented an analysis of the end-results of his hip arthroplasties, which were 60 in number. In the estimation of the results the requisites of function, stability, endurance, and durability were taken into consideration. There were 47 cases of single ankylosis, and in 24 of this number sufficient time had elapsed from operation to judge the final outcome. Only 15 could be traced. Excellent results were obtained in 10 of these cases, a fair result in 1, and a doubtful result in another. Although there were no deaths from operation, 1 patient died a year after the arthroplasty and Campbell attributed the cause to the operation. Ankylosis recurred in 2 cases. Six of the group of 10 proved that the new joint can withstand the effect of time, having been operated on from three and a half to ten years previously.

Campbell reported his experience in bilateral cases in an article published in 1926. In 25 arthroplasties for bilateral ankylosis in 13 patients, single mobilizations were performed in 7 cases, double arthroplasties in 2 cases, 3 arthroplasties each in 2 cases, and 4 arthroplasties each in 2 cases. From a functional point of view, only 5 results may be considered good, and 1 fair. Five patients, however, secured a great deal of relief from the restoration of satisfactory motion in one hip and the correction of deformity in the other. In no case was there a practical range of motion obtained in both joints. There were 7 cases in which infection was stirred up, in 2 of which death occurred.

As to technique, Campbell used pedicled fascial flaps in some of his early cases, but he has now abandoned their use except when a free transplant cannot be easily obtained. His method, in brief, is as follows: The U-shaped skin incision of Kocher is made. The

deep fascia and gluteal muscles are incised in the same direction. The great trochanter is severed and dissected upward with the gluteal muscles. A straight incision is made down to and parallel with the entire neck of the femur, extending about 2 inches upon the ilium. The capsule and adherent tissue are separated from the neck and acetabulum. The fusion is severed with a large carver's chisel, and the hip dislocated. The head is modeled to three-fifths or four-fifths of its normal size and smoothed. Superficial bone about $\frac{1}{4}$ inch in thickness is removed from the acetabulum. The cavity is then repolished with a Murphy reamer.

A free transplant of fascia lata, taken from the lateral aspect of the thigh just above the knee on the operated leg, is brought into the wound. One end of the flap is stitched to the soft tissues about the margins of the acetabulum, and is cupped to invest its surface. The other end clothes the head and is held by a purse-string suture. The fascia is also stitched to the adjacent soft parts or fastened through drill holes in the neck. The capsule, deep fascia and skin are closed in the routine manner. Adhesive plaster strips, 2 inches wide, are applied to both sides of the limb from the upper third of the thigh to the ankle, with the free ends extending about 6 inches below the foot. A plaster cast is applied from the ankle on the affected side, and from the knee on the opposite side, to the nipple line. Buck's extension apparatus with from 10 to 20 pounds' weight is applied.

On the tenth day the cast is bivalved from the ankle to just below the crest of the ilium to permit flexion. Passive motion is begun by means of an overhead pulley arrangement, the patient himself directing the movements. Active motion is begun as soon as possible. Physio-therapy should be used for one year.

Through the courtesy of Dr. Campbell we are able to cite one of his cases:

Case XIX.—E. K., aged twenty-four years.

History.—At eighteen years of age this patient suffered an acute infectious arthritis of the toe on the right foot. The infection progressed gradually until the knee and the hip became involved. Ankylosis of these two joints finally resulted.

Physical Examination.—March 30, 1927: The hip was ankylosed in slight abduction. (Fig. 96.) The trochanter was not

above Nélaton's line. The knee was ankylosed in about 35 degrees flexion, with marked outward rotation of the tibia and genu valgum deformity.

Treatment.—March 31, 1927: Dr. Campbell performed an arthroplasty of the hip according to his regular technique.

FIG. 96.—Case XIX. E. K. Roentgen film showing solid bony ankylosis of the right hip in slight abduction, before operation. (Courtesy of Dr. Campbell.)

May 5, 1927: An arthroplasty of the knee was done.

Result.—May 26, 1928: One year and two months after arthroplasty the hip had flexion to 90 degrees, full extension, and about 75 per cent of normal rotation in both directions. The joint was practically painless, and the patient was able to bear weight without support. There was about 40 per cent painless motion in the knee and good stability. (Figs. 97, 98 and 99.)

A large series of hip arthroplasties, comprising 100 cases, in which chromicized pig's bladder was used for flaps, has been reported by Baer.[1] Good results were obtained in 82 per cent of the cases. Under the section on Prognosis we have mentioned the different pathological conditions for which Baer performed arthroplasties, and we have outlined the probable outcome in each type.

FIG. 97.—Case XIX. E. K. Postoperative Roentgen film showing good joint-space in the hip-joint. (Courtesy of Dr. Campbell.)

Baldwin[34] obtained a successful result with the use of Baer's membrane. Dickson and Diveley[35] also reported a good result in a case ankylosed in the position of 70 degrees flexion and 40 degrees adduction. In operation they formed a new joint in the trochanteric

region below the site of the original joint, and sutured the membrane about the distal fragment that corresponded to the head. Durán[36] secured a fair result using Baer's membrane.

FIG. 98.—Case XIX. E. K. Showing weight-bearing, one year two months after arthroplasty. (Courtesy of Dr. Campbell.)

FIG. 99.—Case XIX. E. K. Showing flexion to 90 degrees, one year two months after arthroplasty. (Courtesy of Dr. Campbell.)

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ARTHROPLASTY OF THE JAW.

Ankylosis of the jaw is a serious condition that must be relieved by mobilization. A person with a fixed temporo-maxillary joint is unable to take proper nourishment, with the result that he becomes emaciated and weak. In young children the complications of throat and dental infection, which develop early from lack of hygienic care of the mouth and teeth, add to the gravity of the condition. In spite of the dangers of infection from operative interference, the risk is warranted in order that the patient will be able to eat.

Among the different methods used in treating ankylosis of the jaw is excision. This procedure has been carried out more commonly than any other method, with a fair percentage of satisfactory results. But when excision is used in the jaw, the outcome, as in the case of excision of other joints, is liable to be an unstable joint, which usually has considerable lateral motion. Furthermore, there is the possibility that in time the joint will become arthritic. To ensure stability, several operators, including the writers, advise the

use of arthroplasty. The greatest amount of work in mobilization of the jaw by arthroplastic measures has been done by Baer.[1] His success in 43 cases has led him to recognize arthroplasty of the temporo-maxillary joint as "an operative procedure as permanent and exact as is the operation of appendectomy."

Etiology.—The temporo-maxillary joint is subject to a great variety of lesions of both traumatic and infectious character. A blow or fall on the chin is of common occurrence. Such accidents often result in fracture or in a traumatic periarthritis. If a focus of infection is present in the vicinity of the trauma the danger of ankylosis is increased. We have seen one case of stiffness which we believed was due to a birth injury. Infection may enter the joint directly, or it may be carried into the jaw through the blood from infectious foci elsewhere in the body. Common sources of infection are scarlet fever, measles, typhoid, diphtheria, tonsillitis, otitis media, osteomyelitis of the jaw, abscesses of the teeth, and poly-arthritis. Operators differ in their opinion as to whether trauma or infection is the more frequent cause of ankylosis of the temporo-maxillary joint. Blair[2] concluded from a review of literature that 50 per cent of the cases of articular ankylosis of the jaw were due to injury of the chin. Risdon,[3] in an examination of a series of 17 cases, found 14 of traumatic origin. Henderson and New,[4] on the contrary, noted that only 20 per cent of a series of 23 cases were due to injury. Orlow,[5] in an analysis of 104 cases, found that only 29 per cent were caused by trauma.

Age.—True articular ankylosis of the jaw is seen most frequently within the first ten years of life. It often develops during the feeding period, when an infant's general health begins to fail. In such cases it may be impossible to trace the cause of the stiffness. Adult cases of ankylosis, which are less common, are usually the result of a low-grade infection about the mouth, a process that is part of a general chronic arthritic condition. The failing health and loss of weight in these cases call for early interference.

Pathology.—Ankylosis of the fibrous variety is due to the presence of fibrous adhesions either in the periarticular tissues or in the intra-articular structures. If the fixation is bony in character the joint may be entirely obliterated, the condyle and the zygoma forming

[1] Baer: Arthroplasty of the Hip (see conclusions), Jour. Bone and Joint Surg., 1926, **8**, 791.

one bone. In ankylosis of the jaw it is not unusual to find both intra-articular and extra-articular pathology.

The occurrence of ankylosis at an early age in life, before the jaw is fully formed, always interferes with the development of the involved side, and not infrequently affects the growth of both sides. Possibly the lack of development of both sides in a unilateral ankylosis is caused by disuse. Involvement of the affected side is due to the destruction of the epiphysis, upon which the growth of the ramus depends to a great extent.

Physical Characteristics.—Cases of unilateral ankylosis of the jaw, when the involvement has occurred early in life, present a typical picture of deformity. The lower dental arch remains behind the upper. The chin recedes and is displaced toward the affected side. The ankylosed side of the face appears rounded, whereas the normal side appears flattened. The mid-line of the lower jaw diverges to the ankylosed side when the face is in repose, and if movement is possible the mid-line will be seen to shift more and more to the ankylosed side as the patient opens his mouth. The explanation of this shifting lies in the movement of the condyle of the affected side, which travels forward as the mouth is opened.

In bilateral cases, or in unilateral cases that develop after full growth of the jaw and have not a clear history of the onset, it may be difficult or even impossible to determine the location of the ankylosis.

In cases of fibrous ankylosis the mouth may be closed tightly or a slight opening may be possible. In the bony variety the joint is firmly fixed. Roentgen films will demonstrate a true bony ankylosis, although clinically it may be difficult to determine its presence.

Treatment.—Forcible opening of the mouth by manipulation may be of some use in breaking up simple joint adhesions in an incomplete fibrous ankylosis. If, however, the union is a firm fibrous one, or if the fixation is bony in character, the results of manipulation are not permanent. Operative interference is required in such cases, but before it is carried out an attempt should be made to restore all motion possible. For this purpose, wedge screws (Fig. 100) should be used, and stretchings should be done morning and night. If motion is present to any degree an attempt is made to increase it by such means as excessive chewing.

Operative Technique (Writers'). A two-day preparation is given to the area extending 2 inches around the ear by painting the skin with a solution of hexyl resorcinol. Another preparation of the same nature may be given on the morning of the operation.

A modified L incision gives the best exposure. The incision is made about 1 inch in front of the ear, beginning $\frac{1}{2}$ inch above the zygoma, passing downward over the joint in a modified L-shape, and terminating 1 inch forward on the ramus of the mandible. (Fig. 101.) Care must be taken to keep forward of the facial nerve and artery. The flap is dissected forward. The temporo-maxillary joint is exposed by blunt dissection, and the capsule incised and

FIG. 100.—Corkscrew wedge.

retracted. By means of a curved osteotome the head of the mandible is separated from the joint cavity as near the articular line as possible, the operator following the joint contour as best he can. (Fig. 102.) When the head has been freed the joint cavity is reshaped by making a slightly concave surface against which the newly-formed head of the mandible will rest. A small burr about $\frac{1}{2}$ inch in diameter is used for this purpose. By careful filing $\frac{1}{4}$ inch of bone is then removed from the surface of the mandible. The remodeling of the joint surfaces is very important from the point of view of stability.

A piece of fascia lata, which has been removed from the outer part of the thigh, is wrapped around the mandible and sutured

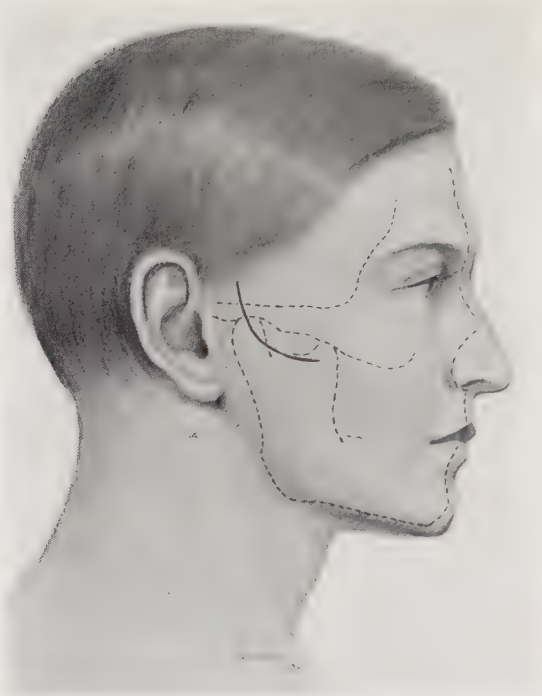

FIG. 101.—Jaw arthroplasty. Skin incision. (MacAusland.)

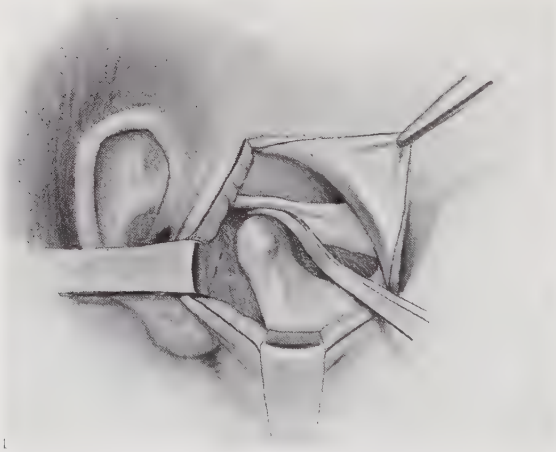

FIG. 102.—Jaw arthroplasty. Freeing head of mandible from joint cavity. (MacAusland.)

tightly. (Fig. 103.) A flap of temporo-maxillary fascia may be used instead of fascia from the thigh, but the removal of a flap in the vicinity of the joint requires a larger incision and is not so practical. The wound is closed in the usual manner.

After-care.—After a period of a week or ten days of rest passive motions are started. The patient is encouraged to control these movements by voluntary muscle contraction. Twice daily a cork-screw wedge is inserted and maintained in position for a few minutes to secure maximum opening of the jaw. (Fig. 100.) No movements should be allowed in the presence of pain. Provided the technique

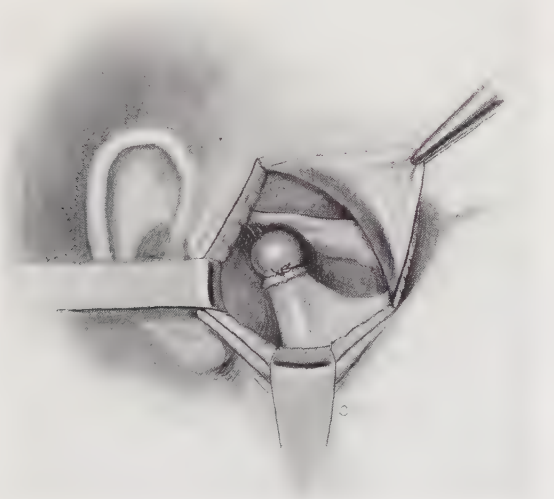

Fig. 103.—Jaw arthroplasty. Showing flap of fascia wrapped around the mandible and reduction of head. (MacAusland.)

has been carefully carried out, the mandible and the opposing concave surface fit properly and cause very little pain as they glide on each other.

Case XX.—B. M., aged four years.

History.—The child had seemed perfectly normal until about six months of age, when the mother noticed that the lower jaw was receding a little. The retraction gradually increased until the child was ten months of age. Since then her condition had remained the same.

Physical Examination.—April 21, 1914: The lower jaw was fixed and drawn backward and to the left. The left side of the

face was full, whereas the right side (the normal side) was flattened. There was no movement up or down in the jaw. The line of the lower teeth was 0.5 cm. back of the upper row.

Treatment.—April 22, 1914: An arthroplasty was performed. The groove between the coronoid process and the articular process lay so high under the zygoma that it was impossible to pass an instrument around the articular process to saw it off. Therefore, the process was chiseled across at the level of the lower border of the zygoma. A gap was left between the imbedded head and the ramus. Two flaps of temporal fascia and fat, with pedicles, were drawn into the gap.

Twenty-four hours after operation the child could open her mouth perceptibly wider than before operation, and she could eat and swallow without discomfort.

FIG. 104.—Case XX. B. M. Showing opening of $1\frac{1}{4}$ inches, thirteen years after the second arthroplasty. (MacAusland.)

May 5, 1914: The child could open her mouth to within 60 degrees of normal. This motion was lost during the next year, and when the child reported again in May, 1915, she could not open her mouth at all.

May 15, 1915: A second arthroplasty was performed. A curved incision was made along the line of the old scar. Large, irregular bony masses filled in the region of the old bone. These were cut away, and a gap of $\frac{3}{4}$ inch in diameter was left. A flap of fat and fascia was stitched about the end of the bone.

May 22, 1915: The child could talk well and eat without pain.

Four years later the child suffered an otitis media suppuration, followed by marked irritation of the auditory canal on the side previously mobilized. Stiffness of the jaw recurred, with marked

swelling in front of the ear. Examination showed that the jaw had developed markedly since the second arthroplasty. The general condition was greatly improved. The present immobility was due to tenderness.

In an exploratory operation a large abscess was found in the region of the parotid gland. After this was drained the jaw could be moved well.

Result.—December 23, 1927: Nearly thirteen years after the second arthroplasty the facial asymmetry was slight. The left cheek was slightly more prominent than the right. The patient could open her mouth $1\frac{1}{4}$ inches. (Fig. 104.) Roentgen films showed a definite deficiency of the left mandible and apparently no condyle.

FIG. 105.—Case XXI. E. F. Ankylosis of the temporo-maxillary joint before arthroplasty. (MacAusland.)

CASE XXI.—E. F., aged fifteen years.

History.—The child had been unable to open her mouth since childhood. At birth some stiffness of the jaw was noticed and there was a question of instrumental injury. Although the condition gradually grew worse, the child had no treatment, since it was expected that she would outgrow the trouble.

Physical Examination.—Both mandibular articulations had some motion up and down and laterally. The lower jaw was receding and undeveloped. Opening to only $\frac{1}{4}$ inch was possible. The teeth were decaying. (Fig. 105.)

Treatment.—June 27, 1928: Jaw screws were applied. (Fig. 100.) These were adjusted during the following month in the attempt to pry open the jaws.

August 23, 1928: An arthroplasty of the left side was performed.

August 28, 1928: There was some swelling of the face and eyes with a purulent discharge from the wound. The incision was opened enough for drainage.

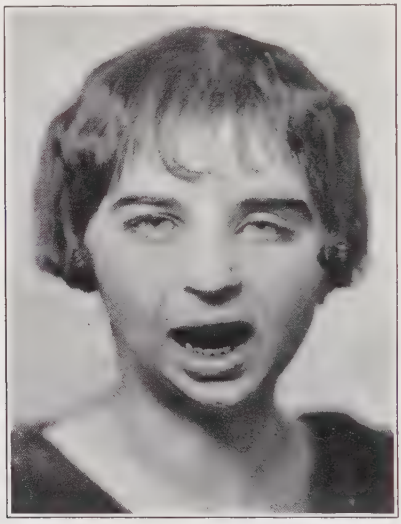

FIG. 106.—Case XXI. E. F. Photograph taken three months after the second arthroplasty, showing free, painless opening of the jaws. (MacAusland.)

September 4, 1928: The septic condition was very much improved.

September 28, 1928: The wound was nearly healed. Stretching of the mouth with wooden screws was to be started. Operation on the other side was to be considered.

October 26, 1928: A regular arthroplasty of the right side was done.

Result.—January 5, 1929: The patient is able to eat and talk well. There is free and painless motion in the jaws. (Fig. 106.)

Résumé of Literature.—The seriousness of an ankylosed jaw led to early attempts to mobilize this joint by arthroplastic methods.

A very large number of cases has been reported in which muscle interposition was used. In Hoffa's[6] collection 18 cases are mentioned, including single cases in which operations were performed by Helferich, Lentz, Mikulicz, Henle, Bilczynski, Kusnetzow, Schmidt, Föderl, Meyer, and Beresowski; 2 cases each by Gluck and Orlow; and 4 cases by Rochet. Flaps from the temporal or masseter muscle were used for interposition in 13 of these cases, with good results. The average separation of the incisor teeth in 10 cases was 2.6 cm. Good results were also obtained in 2 cases in which skin flaps were used. In one instance in which hog's bladder was inserted the incisors could be separated 2.6 cm., and in 2 cases in which gilded plates were used a separation of 2 cm. and 1.75 cm. respectively was possible.

Hoffa himself performed an operation in one case using a flap of the temporal muscle. Good movement resulted, and there was sufficient separation to allow the placing of two fingers between the rows of teeth. Arthroplasties in which flaps of muscle were inserted have also been reported by Riegner,[7] Krause,[8] Kirstein,[9] Demoulin,[10] Ombredanne,[11] Mirotvortseff,[12] Bogoyavlenski,[13] and Fasano.[14] The majority of patients recovered satisfactory motion, being able to open the mouth widely and to eat normally. In Conrad's[15] dissertation on muscle interposition for the prevention and removal of ankylosis there is mentioned one case of ankylosis of the jaw. An arthroplasty, in which a flap of the temporal muscle was used, resulted in an opening of 4 cm.

Kerr[16] reported 2 successful arthroplasties in which flaps of temporal muscle were inserted. One was performed in a case of fibrous and bony ankylosis of both joints with contraction of the periarticular structures. After operation the patient was able to masticate solid food—a marked gain in contrast to the $\frac{1}{16}$-inch opening that had been possible before mobilization. The second patient after operation could open her mouth normally and masticate food, whereas previous to the arthroplasty she had only a $\frac{1}{4}$-inch opening. Kerr used an L-shaped incision, beginning 2 inches above and $\frac{1}{2}$ inch in front of the ear, passing down to a point opposite the external auditory meatus, and then proceeding anteriorly for $1\frac{1}{2}$ inches.

Desgouttes and Perrin[17] cited a case in which a layer of the masseter was interposed following cuneiform osteotomy. One month

after arthroplasty the patient could open her mouth and masticate normally.

Lexer,[18] in 1905, first proposed the use of a free flap of fatty tissue instead of a pedicled flap of muscle. He recognized that a pad of fat could be easily obtained from the cheek. Lexer carried out his method in 5 cases, with good results.

Murphy[19] was the first to introduce the use of fat and fascia for interposition. His technique was as follows: An incision was made in front of the ear, beginning $\frac{1}{2}$ inch below the root of the zygoma and extending for 2 inches to the hair-line. The incision might be curved in and convexed backward, passing forward under the zygoma to 1 inch in front of the ear from a point 2 inches above the zygoma, or it might be L-shaped. Murphy found that the L-incision gave good access. The neck of the mandible was divided, and the bone-ends were separated by traction. The coronoid process was removed. A pedicled flap of fat and fascia, taken from the temporal fascia, was interposed.

In 1913 Murphy reported a series of 9 arthroplasties of the jaw, 7 for bony ankylosis and 2 for extra-articular fibrous fixation. One case, that of a boy with ankylosis (probably fibrous) of the left jaw and bony ankylosis of the right, secured an excellent result, being able to put an apple between his teeth. Arthroplasty in another case, of fibrous ankylosis, allowed the opening of the jaws to $1\frac{1}{2}$ inches three months after operation. A third patient could open his mouth 1 inch five weeks after intervention. Murphy did not state the outcome in the other cases.

Murphy's operation formed the basis of many arthroplasties of the jaw. Prando[20] used this method in one case. Although it became gangrenous, the result was good, and the patient could open his mouth and talk clearly. Douglas,[21] in 1919, performed an operation for complete bony ankylosis of the left temporo-maxillary joint. He made a horizontal incision just above the zygoma, separated the bones, and interposed a flap of the temporal fascia with overlying fat. The final result was excellent. Woolsey[22] performed a similar operation and obtained a good result. He advised keeping the jaws apart for some time after operation. Ritchie[23] turned down a flap of fascia from the temporal muscle in one case. The end-result was good. Bockheimer[24] modified the Murphy technique by making the incision behind the ear, a deviation that had the advantages of

avoiding the facial nerve and of hiding scars. In the case he reported the patient could open her mouth normally fifteen months after mobilization.

Gilpatrick[25] reported a severe case of complete ankylosis of the lower maxilla of fourteen years' duration. The stiffness was the result of scarlet fever complicated by an infection of both mastoids. The food had to be macerated in the plate, and the patient could talk only through clenched teeth. The right side was attacked first in operation. An incision $1\frac{1}{2}$ inches long was made in front of the right ear, beginning at a point $\frac{1}{2}$ inch below the zygoma and extending upward. All new bone was removed. A flap of fat and fascia was interposed. As the jaw could then be opened, the left side was not touched. In ten days the patient could eat.

Carr[26] used the Murphy method in 3 cases and obtained excellent results. Coelho[27] used a flap of fat and temporal fascia in 1 case. Despite the fact that the flap sloughed and a fistula formed, the result was very good.

Chubb[28] reported a method in which flaps of temporal muscle and fascia were used. His technique was as follows: The incision started in the preauricular fold at the lower level of the external auditory meatus, passed vertically upward to the level of the tip of the pinna, and curved forward below the superior temporal crest, to terminate anteriorly within the hair region. The zygoma was exposed and the necessary bone removed piecemeal. The entire coronoid process was removed. Chubb described 5 cases in which he used this method. Four were of traumatic origin and 1 was of infectious origin following a bilateral suppurative arthritis of the temporo-mandibular joints in infancy. A gap of at least 2.5 cm. was obtained in each case, and all patients had good power of mastication.

The next step in arthroplasty of the jaw was to interpose flaps of fascia that had no layer of fat attached. Some operators continued to use pedicled flaps, but others recommended free material. The flaps were secured from the temporal fascia or from the thigh.

Blair[2] considered a pedicled flap of subcutaneous temporal fascia admirably adapted for interposition. His incision was made almost completely within the hair-line. Blair used his technique in 5 cases. The immediate result of operation in all cases was an opening of at

least $\frac{3}{4}$ inch. The space was later increased by means of a rubber bottle-stopper.

Hallopeau and Darcissac[29] obtained an excellent result in a case of incomplete fibrous ankylosis following blennorrhagic arthritis, in which a layer of temporal fascia was used. After operation the child could open her mouth 35 to 40 mm.

Ketcham and Humphrey[30] reported a case in which an arthroplasty had been performed by Freeman. A flap of fascia was turned down from the temporal region. Normal function was restored.

In 1913 Putti[31] reported 3 jaw arthroplasties. He used Abbe's incision, resected enough bone to allow opening the jaw, and interposed a free flap of fascia lata that had been taken from the thigh at the base of the great trochanter. In the postoperative treatment the passive exercises were regulated by means of wooden wedges. The first case, one of total bilateral ankylosis of blennorrheal origin, had nearly normal motion four months after intervention. The third patient, who had suffered a complete ankylosis between the condyle and the glenoid on the left side with deformity of the head of the condyle, could open his mouth fully one year after operation.

Jorge[32] reported a case of bilateral ankylosis of the bony variety, which had existed for fifteen years. After resection of the surfaces of both joints the articular ends were covered with soft tissues. As a result of operation an opening of 3 cm. was obtained.

We have already referred to Baer's[1] success in mobilizing the temporo-maxillary joint. In a series of 43 cases he had only 1 failure. That was the case of a baby with a synostosis of the entire upper and lower jaw. The infant weighed only 4 pounds at one year of age, and operation should never have been attempted. Baer's technique is as follows: The field of operation is scrubbed with potassium permanganate, oxide and bichloride of mercury, ether, and alcohol. The incision is made parallel to the zygoma and along its lowest border. The fibers of the external pterygoid muscle are separated, and the temporal muscle is retracted forward. The condyle is exposed. This is separated from the ramus and the temporal bone. The bones are shaped, and a cuff of membrane (see p. 48 for description of membrane) is sewed to the periosteum of the bone. The muscle is brought together and sewed and the wound is closed. After two weeks the patient is encouraged to use his mouth and the movement is regulated by graduated corks.

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ARTHROPLASTY OF THE SHOULDER-JOINT.

Limitation of motion or ankylosis of the shoulder-joint is not of frequent occurrence. The joint is rarely the site of an infectious joint process, and the shoulder, of course, is not subject to the static disturbance and the traumatic lesions to which weight-bearing joints are exposed. When limitation of motion does occur it is usually due to involvement of the periarticular tissues subsequent to a bursitis, and not to intra-articular damage.

Occasionally one sees a true bony ankylosis of the shoulder, with the pathology localized within the joint proper. In such cases, the head of the humerus is firmly fixed in the glenoid cavity. In addition, adhesions cicatricial in nature are present in the periarticular structures. In most cases the head of the humerus has dropped in its cavity as the result of the pull of gravity upon the capsule, pre-

viously stretched on account of the presence of fluid within the joint. This deformity constitutes a serious complication in mobilization of the shoulder, and unless some measure is included in the mobilizing technique to provide definitely against subluxation, further subglenoid displacement is liable to occur. A joint cannot be functional when such deformity is present, no matter how successful the arthroplasty has been in restoring motion.

Provided ankylosis takes place with the joint in functional position, that is in 45 to 50 degrees abduction, 5 to 10 degrees for-

Fig. 107.—Ankylosis of the shoulder. Position of rest. Note the rotation of the scapula.

ward of the sagittal plane, a stiff shoulder is not a serious handicap. When the arm is in this position the rotation of the scapula, which becomes hypermobile with use, makes it possible for the shoulder girdle to move in almost its normal arc. As the scapula rotates, the arm can be brought to the side, or raised, often as high as a right angle to the body. The compensatory movement of the scapula may so closely approach the normal function of the shoulder-joint that the ankylosis is not detected. (Figs. 107 and 108.) No joint furnishes a more striking example of the advantage of treatment in proper functional position.

It is unfortunate that the relation between the occurrence of ankylosis in good position and the recovery of function through the hypermobility of the scapula is not more often appreciated. The customary position in which one sees the arm maintained following a lesion of the shoulder-joint is that of deformity. The arm is allowed to rest at the side or crossed on the body. Upon recovery, the patient has very limited abduction and is unable to raise his hand to his head. Grave sequelæ may follow. Circulatory dis-

FIG. 108.—Ankylosis of the shoulder. Full abduction obtained by rotation of the scapula.

turbances occur in the elbow, wrist, and fingers, especially in senile patients suffering from traumatic or arthritic lesions. Flexion deformity of the wrist may develop when the arm is allowed to rest at the side. In turn, deformities of the fingers develop secondary to the malposition of the wrist. Finally, the arm may become absolutely useless, a condition that could easily have been prevented had the joint been treated in proper functional position during the initial lesion.

The Treatment of Ankylosis of the Shoulder-joint.—The treatment of a stiff shoulder depends primarily upon the position in which ankylosis has taken place, and to a certain extent upon the age of the patient. If the arm is fixed in malposition, for instance, at the side of the body, operative interference always is required for the purpose of re-ankylosing the extremity in proper functional position. The arm then becomes a serviceable member, and in the majority of cases this result is satisfactory.

Occasionally one sees a young patient who, even with compensatory motion of the scapula, is nevertheless handicapped by the stiff shoulder. A girl is conscious of the defect when she wears evening clothes. A boy is at a disadvantage in sports. Something must be done for these young patients. Although in past years we have steadfastly advised against mobilization of an ankylosed shoulder, we now believe that arthroplasty should be attempted, if only for esthetic reasons, in the case of young adults, when after very careful study the joint seems suitable for arthroplasty.

There are two factors that must be taken into consideration in performing an arthroplasty of the shoulder-joint: One is preservation of the musculature and the other the prevention of subluxation of the humeral head. These two factors seem to have been disregarded in the few arthroplasties reported in literature, since operators have complained of the tendency of the muscles around the joint to become paralyzed and atrophic after a mobilizing process, and subluxation often continued to increase. The result was that the joint, although mobile, was not functional. The method devised by the writers provides for the preservation of all the muscle attachments, and guards against further displacement of the head of the humerus by the use of a fascia lata loop to maintain the head in normal relation to the glenoid cavity. This step represents a new development in the technique of arthroplasty of the shoulder, which thus far we have had occasional to use in only 1 case of ankylosis. (The same procedure has been used successfully in 2 cases of recurrent dislocation of the shoulder.)

Arthroplastic measures are not to be considered when the deltoid muscle is absent.

Operative Technique (Writers').—A longitudinal incision, running parallel to the shaft of the humerus, is made from the tip of the acromion process down the anterior surface of the arm to the

insertion of the deltoid. The deltoid muscle, which usually is extremely thin and atrophied, is carefully separated, care being taken to make only blunt separation of the fibers. The capsule is exposed and incised. The capsule and all scar tissue are separated from the humerus, a separation that is often difficult. The point of fusion is usually found to be on the anterior-inferior surface of the glenoid, and it may be small in area. The humerus is freed from the glenoid, and the head of the humerus is smoothed with a concave

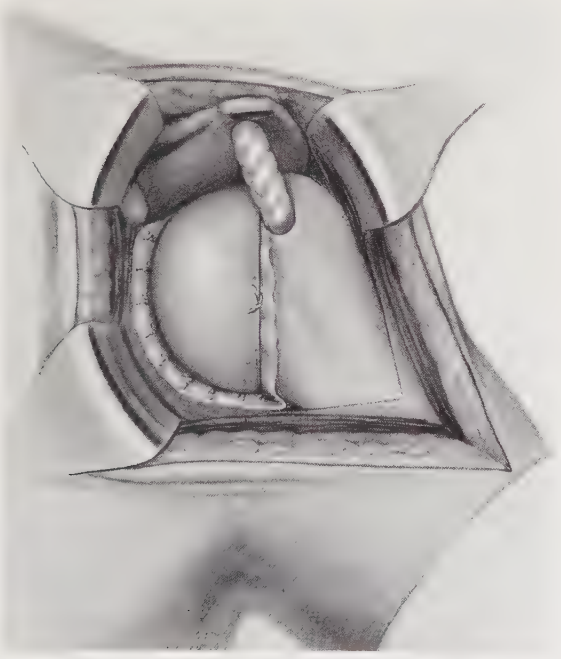

FIG. 109.—Shoulder arthroplasty. Flap of fascia in place and fascia loop holding humeral head in the glenoid. (MacAusland.)

burr. The glenoid is reamed out. A hole $\frac{3}{8}$ inch in diameter is drilled in the antero-posterior plane through the humeral head close to the line of the anatomic neck. Another hole similar in diameter is then made through the outer end of the acromion.

A strip of fascia lata, about 8 inches in length and 2 inches in width, is removed from the upper part of the thigh. A second strip of fascia, 5 inches long and 3 inches wide, is removed from the lower part of the thigh, where the fascia is thickest. The latter

strip of fascia is carefully fitted over the newly-formed head of the humerus, leaving the inner end free, and is held in place by a purse-string tie. The free inner end of the fascia is sutured around the edges of the newly-formed glenoid cavity. The first strip of fascia is curled into a rope and passed through the drill-hole in the humerus, and then brought through the drill-hole in the acromion. With the shoulder abducted to 60 degrees the rope of fascia is tightly sutured. By means of the loop thus made, the humerus is held firmly up in the glenoid, but at the same time the loop in no way restricts joint motion. (Fig. 109.)

The wounds are closed in the usual manner. A plaster shoulder spica is applied with the shoulder in 60 degrees abduction, 20 degrees anterior to the mid-sagittal plane.

After-treatment. -The arm is maintained in a plaster shell until the deltoid recovers power. Three weeks after operation the upper half of the cast is removed to allow massage and gentle passive motion. Active movements are begun as soon as sensitiveness and pain have subsided. Swimming is the most satisfactory form of exercise, as it eliminates gravity and allows active use of the arm in the favorable position of abduction. Motion should never be forced or attempted in the presence of pain or soreness. Care is taken to prevent strain on the deltoid for a period of several months. Only when this muscle is able to hold the arm in abduction is the splint removed.

Case XXII.—H. H., aged twenty-five years.

History.—The right shoulder was the seat of an infectious process, undoubtedly of Neisserian origin.

Physical Examination.—April 16, 1926: The right arm was considerably swollen about $\frac{3}{4}$ inch below the acromion, especially anteriorly. There was a sore spot on the shoulder. Flexion to only 3 to 4 degrees was possible, and abduction was limited to about 5 to 10 degrees, with pain. Roentgen films showed a light area just below the epiphyseal line of the greater tuberosity, and a small area of calcification in the subdeltoid bursa.

Treatment.—Stretching of the shoulder was advised.

April 28, 1926: Full abduction was easily held. A certain amount of pain continued, and the shoulder was very sensitive to the touch. A suggestion of roughening, crepitant in character, was felt throughout the deltoid muscle.

May 6, 1926: A few degrees of motion without pain were possible. An abduction arm splint was applied.

June 5, 1926: A few degrees of painless motion in all directions were possible. Baking, massage, and gentle movements up to the point of pain were to be continued.

June 21, 1926: The brace was discontinued. The patient was to start floating the arms in deep water.

July 14, 1926: There was 10 degrees abduction and 5 degrees antero-posterior motion. The patient was having some pain. Manipulation was advised.

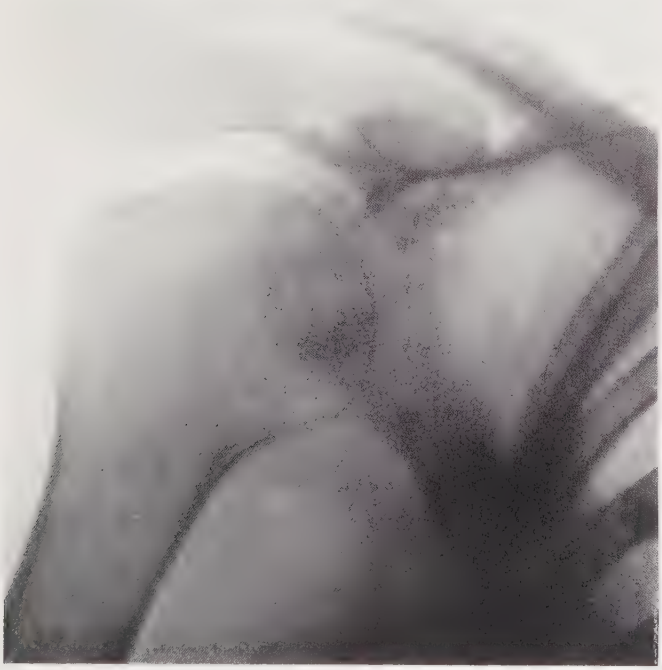

FIG. 110.—Case XXII. H. H. Roentgen film showing slight sagging of the humeral head and erosion of the cartilage of the glenoid. (MacAusland.)

July 27, 1926: A manipulation under ether was done. A great deal of motion was gained, and it seemed that it might be preserved.

September 27, 1926: The motion gradually shut down until only 5 degrees were possible. The shoulder was fixed in about 35 degrees abduction. There was only a spring in other directions. Roentgen film (Fig. 110) showed no cartilage destruction of the humerus, but the glenoid cast a furry shadow in its inferior border. Another manipulation was advised.

October 13, 1926: Fifteen to 20 degrees of motion were obtained by manipulation under ether. This motion gradually shut down,

until *January 21, 1927*, the arm was ankylosed in about 20 degrees abduction, 10 degrees forward of the midline. The deltoid and scapular muscles had distinctly improved, and the patient could raise her arm to her ear and hair.

January 11, 1928: An arthroplasty was done according to the technique outlined above.

February 4, 1928: There was 10 to 15 degrees of motion in the shoulder. Baking and gentle stretching were to be continued. The plaster bandage, which had been bivalved, still remained on.

February 29, 1928: The plaster bandage was removed, and a splint applied, which was to be worn day and night. The arm was not to be lowered. The patient had about 10 degrees of motion and a little rotation. Hot fomentations and gentle manipulations were advised.

FIG. 111.—Case XXII. H. H. Showing return of deltoid power. Complete arc of abduction not fully gained to date.

March 31, 1928: There was about twice as much motion. The patient had no pain. The brace was still being worn as a check on abduction.

May 25, 1928: There was 10 degrees of external rotation and 15 to 20 degrees of flexion. The deltoid muscle was recovering power. The patient was to use the shoulder as much as possible, especially by swimming.

Result.—July 26, 1928: There was abduction of about 35 degrees, forward and backward motion of about 30 degrees, and rotation of about 25 degrees.

November 21, 1928: Shoulder is stable. Motions are within 30 degrees of normal. Rotations are decidedly increased. Patient can get her hand behind her head. (Fig. 111).

Résumé of Literature. The attempts to mobilize the shoulder-joint have been few. In the want of an arthroplastic measure that would result in a stable as well as a functional joint, most surgeons have been content to ankylose the shoulder in good functional position in order to make use of the motion provided by the scapular muscles. Some operators have outlined the technique which they would use in performing an arthroplasty of the shoulder, but they have made no practical use of their methods.

Neff[1] advised reaching the joint through an incision, $3\frac{1}{2}$ inches long, extending from the base of the coracoid process and on a level with it, down on a line with the bicipital groove. The cephalic vein serves as a guide. The greater tuberosity is divided by means of a Gigli saw and retracted upward. Fascia or capsule may be used for flaps.

Murphy[2] did not report an arthroplasty of the shoulder, but he outlined his technique on the cadaver as follows: The skin and deltoid are split, and the fascia is separated along the anterior margin for 4 inches. The fascia is elevated to expose the coracoid process, the head of the biceps, and the coracobrachialis. The process is divided $\frac{3}{4}$ inch from the tip and displaced outward. The ankylosis between the glenoid fossa and the head of the humerus is chiseled through, and an additional excavation of the glenoid fossa is made. An incision is made across the chest over the middle pectoralis major muscle, at a right angle to the original incision. A flap of fat, aponeurosis, and pedunculated muscle is placed between the head of the humerus and the glenoid fossa. The anterior portion of the deltoid may also be used as a flap.

The first use of arthroplasty in a shoulder case was reported by Nélaton[3] in 1903. The operation was done by Coville. An incision 10 cm. in length was made, beginning below the clavicle, passing externally to the coracoid process, and continuing down the arm in the direction of the deltoid. The joint was uncovered by division of the deltoid at the edge of the skin wound. The head of the humerus was divided at the level of the anatomic neck. A piece of the deltoid, obtained by a transverse section, was interposed between the surface of the humerus and the glenoid cavity. The superior portion of the flap was left adherent to the deltoid. A counter-incision was made at the same level, and a thread was passed through the opening, and brought around the extremity of

the muscular strip in loop form. By tightening the thread, the muscle was brought into the articular cavity. Active motion forward and backward was obtained, but abduction was limited.

Hofmann,[4] in 1908, reported a case in which he used a periosteal transplant from the tibia. The result was excellent. One year after operation the rotary movements were almost normal. There was active abduction with a fixed scapula up to 45 degrees, and further abduction when the scapula moved with the arm.

Ringel[5] demonstrated a case in which there had been a complete shattering of the shoulder region. A pedunculated muscle flap from the deltoid was used in the operation. The immediate result was so good that the patient returned to the army. Later it was found that the flap had sloughed and new bone had formed. A second arthroplasty was done, in which a broad flap of fat and fascia from the thigh was fixed over the humerus. Free passive motion in all directions was obtained, but the arc of active motion was limited because of the extensive atrophy of the deltoid.

Steindler[6] reported a case of ankylosis of the shoulder that was due to caries sicca. An arthroplasty was performed in which a pedicled muscle flap from the deltoid was used. While the patient was under observation, a period not designated by Steindler, the mobility was good.

Verrall[7] exposed the joint along the anterior border of the deltoid and dislocated the humerus through the wound. The glenoid was hollowed into shape, and $\frac{3}{4}$ inch of bone was removed from the humerus. A flap of subcutaneous tissue, taken from the deltoid, was turned over the glenoid. Verrall used this method in only one case, and he did not report the result.

Thomson[8] reported a case in which he made an anterior incision, removed the greater part of the humeral head, and stitched a piece of fascia lata over the resected bone-end. The limb was put in a plaster bandage in the position of right-angle abduction. A range of movement sufficient for ordinary use was secured.

Grange,[9] in 1920, performed an arthroplasty for a shoulder-joint ankylosed in a slightly abducted position. There was extensive destruction of the head and greater tuberosity. Three incisions were made: One along the lower border of the clavicle and extending down the front of the arm for 3 inches; one just below the acromion process to meet the first; and one along the lower border of the

pectoralis major. The pectoralis major was divided where it crosses the axilla. The anterior half of the deltoid was cut through $\frac{1}{2}$ inch below the acromion process and turned down. The short head of the biceps, the coracobrachialis, and the pectoralis minor were then divided. The humerus was exposed and rounded. A large flap of superficial fascia was turned in from the surface of the pectoralis major. The wound was closed, and the arm placed in a plaster bandage with the shoulder abducted 45 degrees. Active abduction to 45 degrees, flexion to 45 degrees, and rotation of 60 degrees resulted. Passive abduction and flexion could be obtained to 90 degrees.

W. L. and C. P. Brown,[10] in 1914, reported a case in which they obtained an excellent result. They recommend the use of a portion of the short head of the biceps for interposition. This muscle is located correctly from an anatomic point of view and is covered with a tendinous sheath. Its attachment to the coracoid process places the pedicle in the right position. An incision in the shape of a reversed letter S is made, beginning at the junction of the middle and outer thirds of the clavicle, passing outward half-way between the coracoid and the acromion processes, then inclining forward and downward to the vertical line of the inner side of the arm, and then downward and backward to a point $4\frac{1}{2}$ inches directly below the acromion process. The capsule of the joint is opened and severed sufficiently to mobilize the joint. The head of the humerus is separated from the glenoid fossa, the operator preserving, if possible, the head of the biceps.

To obtain the flap for interposition the tendinous attachment of the inner head of the biceps is exposed. The tendon of the pectoralis major is transfixed with a linen thread and cut loose from the humerus. The attachment of the inner fibers of the deltoid is transfixed and severed from the humerus to facilitate its retraction. The forefinger of the left hand is passed beneath the inner head of the biceps to separate it from the coracobrachialis. Its sheath and fibers are cut across $4\frac{1}{2}$ inches below its attachment at the glenoid cavity. About one-half the muscle, of fan-shape, is used for the flap. This is drawn into place by guy-ropes.

The operators recommend that the capsule should be sutured if it allows good motion; otherwise it should be free. If the pectoralis major is contracted it should not be reattached to the humerus unless it has been lengthened.

The arm is placed in a plaster bandage at a right angle to the body, and with the forearm flexed if the head of the biceps has been severed. In ten days the cast and sutures are removed and gentle passive motion is begun.

The case of ankylosis, in which the operation was performed, resulted in perfect motion. The patient, a carpenter, resumed his trade in six weeks. There was some restriction of the arc of motion because of periarticular contraction in the lower part of the capsule, but two years after intervention the patient had recovered practically the entire arc of motion.

Jerusalem[11] more recently reported a successful case in which a flap of fat taken from the pectoral region was interposed. The case was one of ankylosis from caries of the shoulder in childhood. After operation the patient was able to raise his arm above his head.

Lexer[12] has reported more arthroplasties of the shoulder than any other operator. His series includes 12 cases, the majority of which were ankylosed joints. Ten cases were successful, 2 were questionable, and there was only a single failure. Lexer used a curved incision, beginning over the acromial process, which was chiseled off, and proceeding along the lower border of the clavicle to its middle third, from which the fibers of the deltoid were separated. The incision then followed along the anterior edge of the deltoid to its attachment to the humerus.

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ARTHROPLASTY OF THE WRIST-JOINT.

Arthroplastic measures are only occasionally advisable in the wrist-joint. Since freedom of movement in this joint is most useful

for the ordinary functions of life, there must be definite reasons to account for the few attempts at restoration of motion.

FIG. 112.—Ankylosis of wrist in position of strength—a most important factor in all wrist cases.

One explanation lies in the pathological involvement of the phalangeal joints, tendons and tendon sheaths that is usually found in conjunction with a lesion of the wrist-joint. Particularly is this

true if the etiological process in the wrist was of an acute septic or chronic arthritic nature. When the tendons and the tendon sheaths of the hand are involved, the finger motion becomes limited. The ultimate benefit of an arthroplasty of the wrist in many of these cases, in which multiple lesions are present in the hand, would be uncertain, even though motion was restored to the wrist-joint. On the other hand, if the finger disturbances are only mild, mobilization would not be affected by these complications. In fact, the restoration of motion in the wrist would increase the strength of the fingers.

FIG. 113.—Ankylosis of wrist in position of weakness (flexion). Note compensatory contraction of phalanges.

The more important explanation of the rare applicability of mobilizing procedures to the wrist-joint lies in the fact that a wrist ankylosed in hyperextension with little or no accompanying stiffness in the fingers is a functional member. (Fig. 112.) Unless one is certain of obtaining by arthroplasty more than 10 degrees of painless motion, the wrist is better stiff, since the restoration of only a few degrees of movement leaves the joint open to strain. Practically, the wrist with a few degrees of motion is weaker than a stiff wrist, which is not subject to strain, and which may be used in heavy work and sports. In view of the great advantage afforded by the hyperextended position, one readily appreciates the importance of treating in functional position any lesion of the wrist-joint that is likely to

terminate in ankylosis. The nature of the existing pathology in no way affects this principle. Various types of support, such as plaster shells, leather armlets, or hyperextension wrist splints may be used for this purpose.

If deformity has developed, it should be corrected immediately by manipulation under ether, and the hand maintained in hyperextension. In long-standing cases of structural flexion deformity, the removal of a bone wedge, or a partial excision of the carpus is required.

Unfortunately, the majority of wrist-joints become ankylosed in flexion, the position of deformity. (Fig. 113.) This is because a patient suffering from an acute lesion of the wrist-joint, unless prevented, holds his hand in flexion, the position that seems to afford the greatest relief from pain. This tendency is observed particularly in cases of chronic arthritis. If the patient continues to hold his hand in flexion, ankylosis eventually takes place in this position, making function of the hand impossible. Atrophy of the muscles as well as of the carpal bones occurs from disuse. In adults susceptible to arthritis, a periarthritis often develops in the wrist and fingers and occasionally in the shoulder from disuse. Secondary deformities may develop in the phalangeal joints. All such sequelæ can be avoided if the importance of maintaining the wrist in functional position is appreciated.

Indications for Arthroplasty.—There are occasional cases in which arthroplasty is advisable. Very often a patient whose wrist is ankylosed in hyperextension is unable to make a fist as the result of periarthritis in the fingers, a frequent complication in wrist-joint lesions. The restoration of the wrist motion in such cases increases the strength and motion in the fingers. Arthroplasty may be advisable in judiciously selected cases of young adults, who are handicapped in professional or occupational pursuits by an ankylosed wrist. Needless to say the restoration of motion is of great advantage from an esthetic point of view. In the consideration of the advisability of arthroplasty, such important factors as the nature of the etiological process, the possibility of an active focus of infection, the physical condition of the patient, as well as his social and occupational status must be carefully weighed.

Arthroplasty.—Before mobilization is attempted, it is important to restore as much movement in the fingers as possible. Local thera-

peutic measures, such as baking, massage, and gentle exercises will often improve the motion in the fingers, as well as improve the nutrition of the muscles and skin.

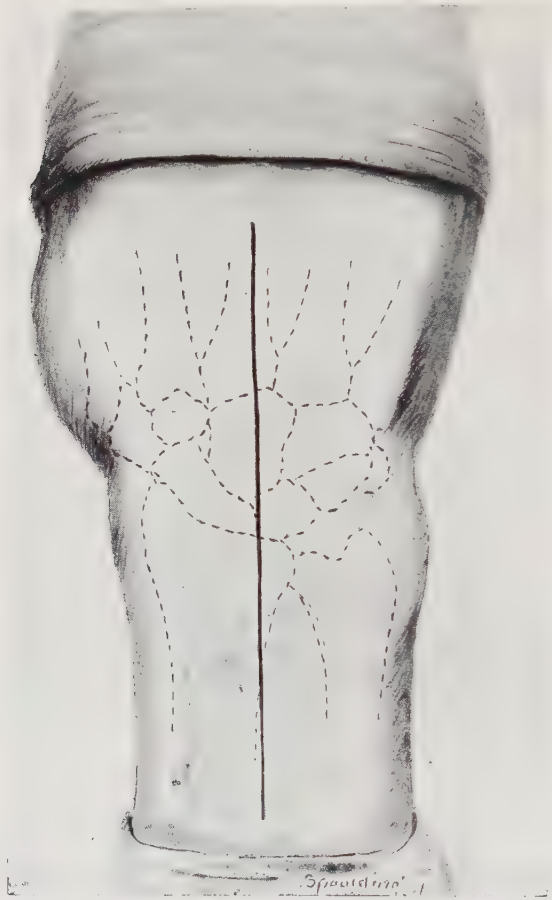

FIG. 114.—Wrist arthroplasty. Line of incision. (MacAusland)

If deformity is present, one should consider the necessity of its correction before performing an arthroplasty. Extreme flexion deformity must always be corrected by a preliminary manipulation. If the flexion is only slight, or if the wrist is ankylosed in a straight position, correction of the malposition may be made at the time of the arthroplasty.

Preliminary intervention may also be advisable to free the tendons from cicatrized tissue. If the tendons are badly damaged, they may be repaired by substituting fascia or strands of silk.

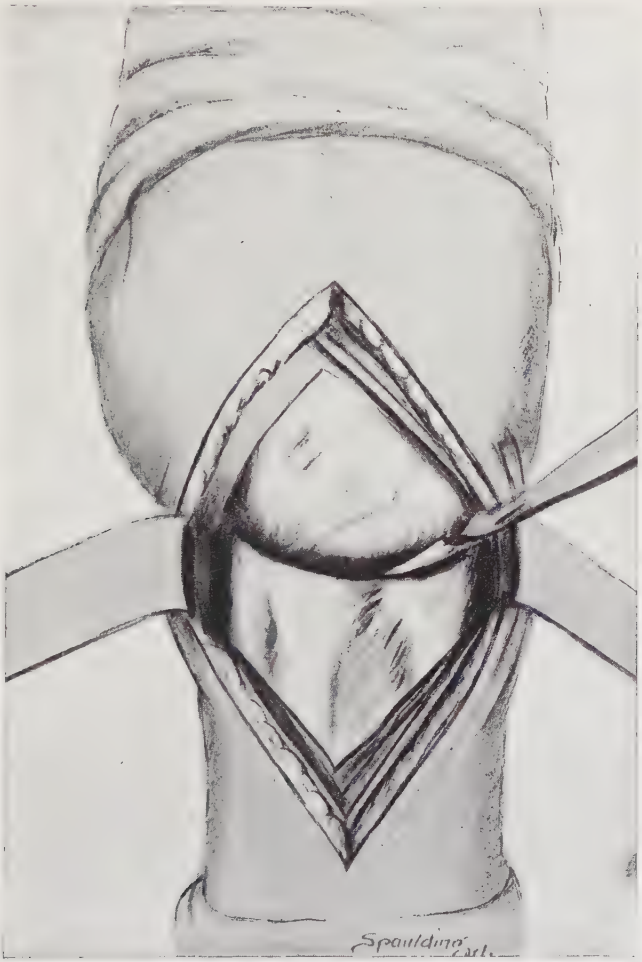

FIG. 115.—Wrist arthroplasty. Cutting out joint-line with curved chisel. A small amount of bone is removed. (MacAusland.)

Operative Technique (Writers').—The operative area, extending from above the elbow to the fingers, is given a two-day preparation. A posterior incision 5 inches in length is made over the wrist-joint and carpus. (Fig. 114.) The skin and superficial fascia are clamped off with towels. An incision is made through the fascia and the pos-

terior ligament and these structures are retracted. The common extensors of the fingers and the thumb are removed from their

Fig. 116.—Wrist arthroplasty. Smoothing the radial and carpal ends with a file. (MacAusland.)

sheaths. The extensor tendons of the fingers are retracted outward, and the tendons of the thumb inward. An incision is then made over the capsule of the wrist-joint. The capsule is retracted laterally

and carefully preserved. With a curved chisel, the scaphoid and semilunar are separated from the radius. (Fig. 115.) The lower end of the radius is reshaped as nearly like the normal radial end as

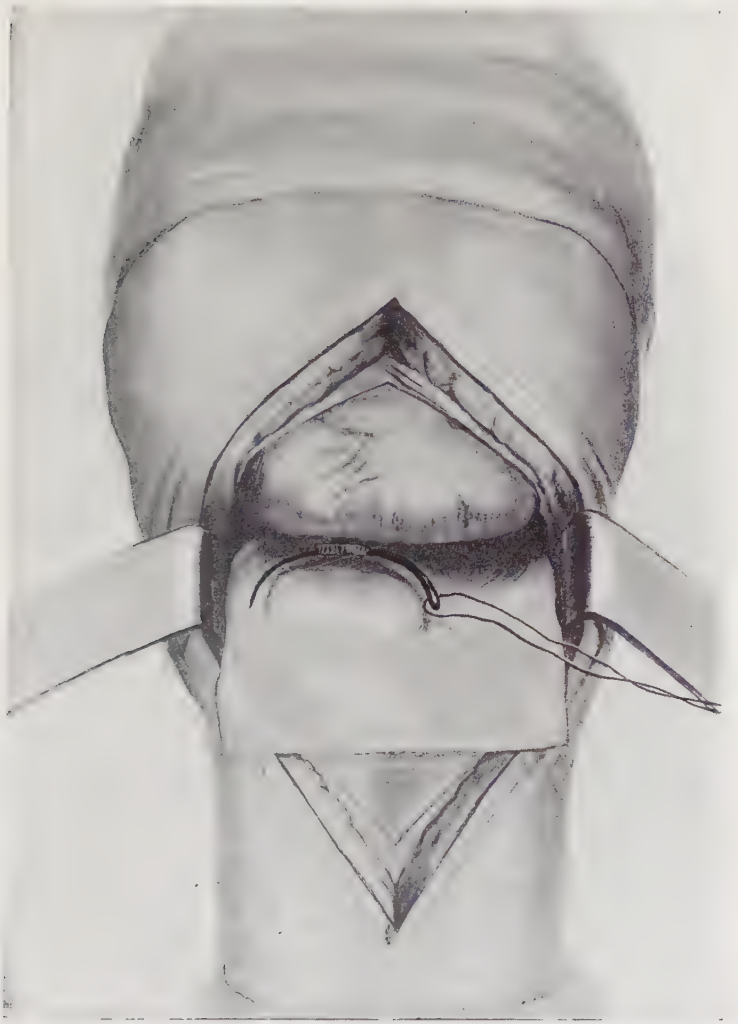

FIG. 117.—Wrist arthroplasty. Suturing fascia lata to anterior capsule. (MacAusland.)

possible. One-quarter inch of bone is removed from the carpus, and the carpus rounded to conform in outline to the opposing radial end. (Fig. 116.) A piece of fascia, which is removed from the outer side

of the lower thigh, is sewed between the bone surfaces with interrupted chromic gut. The fascia is first folded down over the anterior

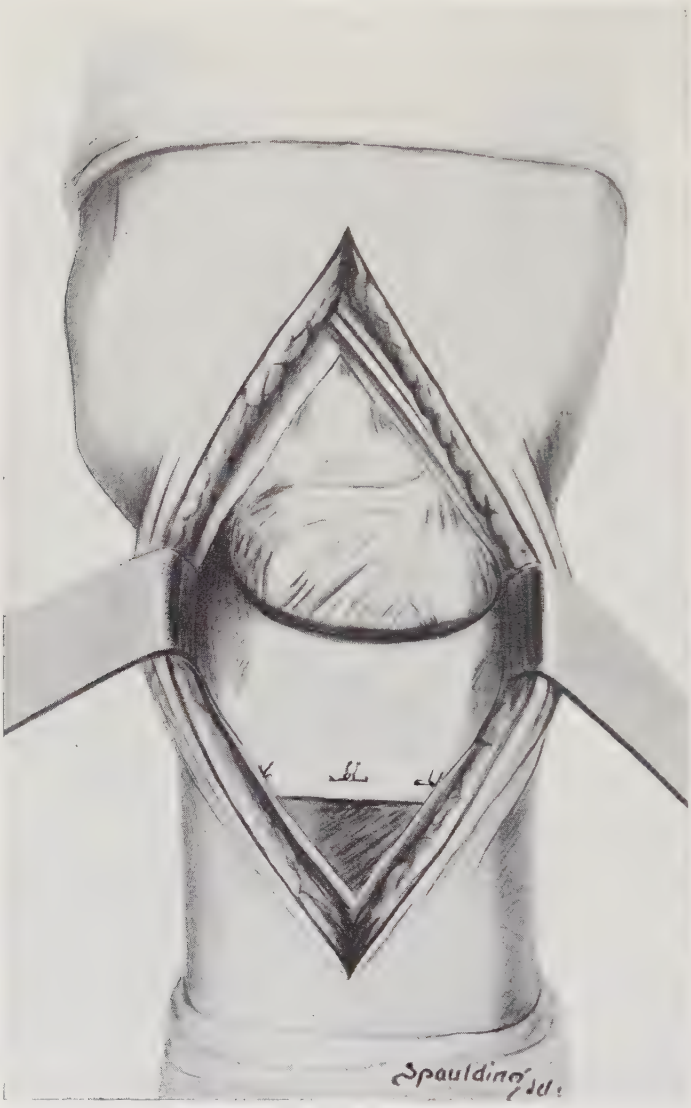

FIG. 118.—Wrist arthroplasty. Suturing fascia lata to posterior capsule. (See text for new step in technique. (MacAusland.)

surface of the joint, covering the carpus, and sutured to the anterior capsule; then it is swung up over the radius and ulna and sutured to

the posterior capsule. (Figs. 117 and 118.) A double layer of fascia is thus interposed into the joint. The old posterior capsule of the joint is then closed with interrupted chromic catgut, and the skin with continuous catgut. The hand is placed in a plaster bandage in hyperextension. (Fig. 123.)

The removal of the tendons from their sheaths is not approved by some operators because of the possible development of adhesions. In our experience we have had no difficulty. Provided the operative technique is non-traumatic, and provided the tendons are well covered with subcutaneous fat and fascia when they are replaced in their sheaths, there is little possibility that adhesions will form.

After-treatment.—The wrist is immobilized in a plaster bandage for a period of about ten days. Upon the removal of the bandage, the wrist is still maintained in hyperextension. For this purpose, either an anterior plaster shell or a hyperextension splint may be used. Passive movements are carried out very gently at first. Therapeutic measures, such as baking and massage, are of benefit in restoring function. As soon as the sensitiveness disappears, the movements are increased, until finally active motion is possible. At all times active use of the fingers is encouraged. Such exercises as squeezing a soft rubber ball, shuffling cards, and swimming are most beneficial. Active use in moderation is often of more benefit than passive efforts regulated by an attendant, who unknowingly may force motion and by so doing keep the joint sensitive.

Case XXIII.—E. M., aged twenty-three years.

History.—On *May 12, 1922,* this patient fell through a pane of glass, cutting his right wrist. Infection set in and resulted in ankylosis.

Physical Examination.—The wrist was stiff in 25 degrees flexion. All the muscle groups had power, but the patient was unable to make a fist. Scars from the numerous incisions made during the septic process were present. A Roentgen film showed considerable atrophy and periarticular changes, with some posterior displacement of the tip of the ulna.

Treatment.—August 5, 1922: The wrist was manipulated into hyperextension, and a plaster bandage applied.

August 23, 1922: The patient could bend his fingers. Use of the fingers while the wrist was still in a plaster bandage was encouraged.

September 14, 1922: The plaster bandage was removed, and a hyperextension splint applied. Daily baking, massage, and stretching were advised.

October 28, 1922: The wrist was rigid in good position. The motion of the fingers had improved, but the patient still could not make a fist. (Figs. 119 and 120.) A Roentgen film showed ankylosis between the scaphoid and the radius and between the semilunar and the radius. (Figs. 121 and 122.)

FIG. 119

November 13, 1922: An arthroplasty was performed according to our regular technique.

November 20, 1922: Roentgen films of the wrist in the plaster bandage showed a separation between the carpus and the radius. (Figs. 123 and 124.)

November 27, 1922: The hand was in good position. The use of the fingers had increased. There was no pain. A hyperextension splint was applied and daily bakings and massage with passive motion were begun.

Result.—September 13, 1928: Nearly six years after arthroplasty the wrist had 10 degrees lateral motion, flexion of 10 degrees, and hyperextension of 35 to 40 degrees. (Figs. 125, 126 and 127.)

FIG. 120

FIGS. 119 and 120.—Case XXIII. E. M. Ankylosis before arthroplasty. (MacAusland.)

The patient could make a moderate fist. His inability to close the fingers completely was due to damage of the tendon sheaths as the result of the old septic process. There was no pain.

FIG. 121.—Case XXIII. E. M. Antero-posterior Roentgen film showing ankylosis of wrist after manipulation. Note the atrophy, periarticular changes, and slight posterior displacement of the ulna. (MacAusland.)

FIG. 122.—Case XXIII. E. M. Lateral Roentgen film showing ankylosis of wrist after manipulation. (MacAusland.)

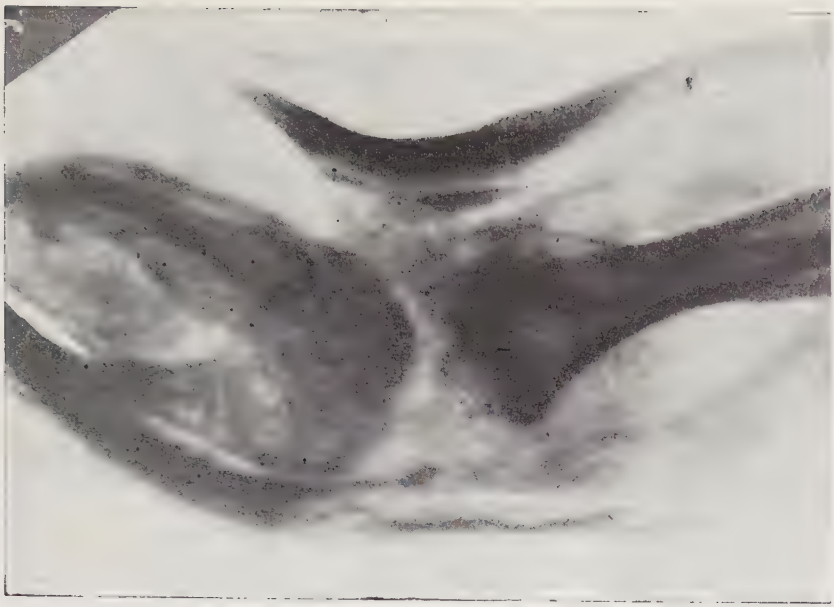

Fig. 123.—Case XXIII. E. M. Lateral Roentgen film of wrist (in plaster) showing the separation between the carpus and the radius. (MacAusland.)

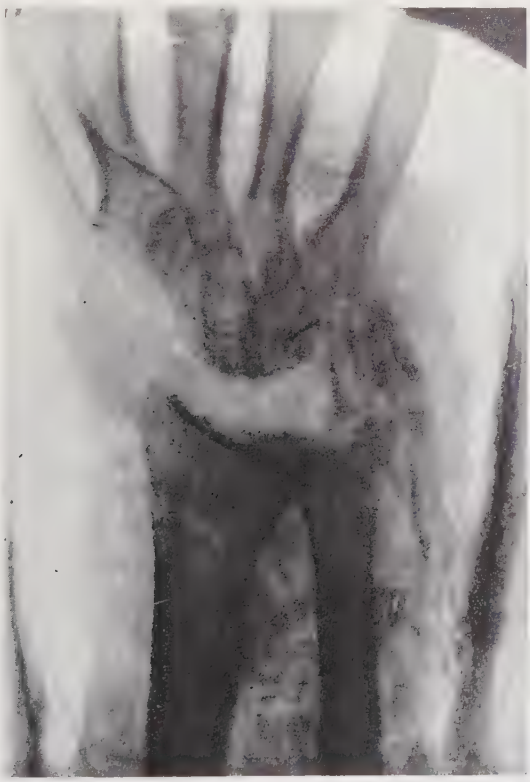

Fig. 124.—Case XXIII. E. M. Antero-posterior Roentgen film of wrist (in plaster) showing the separation between the carpus and the radius. (MacAusland.)

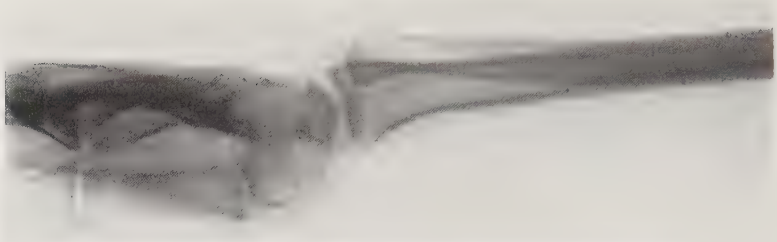

FIG. 125.—Case XXIII. E. M. Lateral Roentgen film showing separation between the radius and the carpus, nearly six years after arthroplasty. (MacAusland.)

FIG. 126.—Case XXIII. E. M. Antero-posterior Roentgen film showing separation between the carpus and the radius, nearly six years after arthroplasty. (MacAusland.)

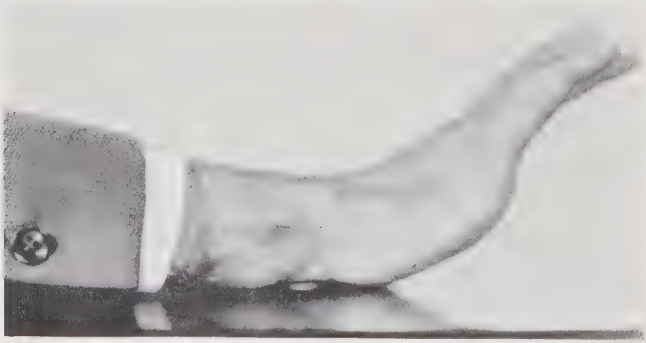

FIG. 127.—Case XXIII. E. M. Voluntary hyperextension, nearly six years after arthroplasty. (MacAusland.)

Case XXIV.—A. H., aged thirty-two years.

History.—A subacute arthritis had resulted in an ankylosed wrist. The joint had been stiff for eight years.

Fig. 128.—Case XXIV. A. H. Lateral Roentgen film showing joint-space between the carpus and the radius. (MacAusland.)

Physical Examination.—The wrist was ankylosed in 45 degrees flexion. The fingers had fair motion.

Treatment.—September 12, 1912: An arthroplasty was done.

October 10, 1912: The wrist was in good position and had about 5 degrees motion.

Fig. 129.—Case XXIV. A. H. End-result sixteen years after arthroplasty. Palmar flexion of the wrist. (MacAusland.)

October 24, 1912: The motion had increased to 10 degrees. At this time the wrist was again stiff in 5 degrees permanent flexion. A manipulation under ether was advised.

November 21, 1912: The adhesions were broken up by a manipulation.

January 16, 1913: A second manipulation was done.

May 8, 1913: The patient had good motion in her wrist, and worked constantly as a nurse-maid.

Result.—January, 1928: More than sixteen years after arthroplasty examination showed the wrist to have excellent stability. It had 10 degrees motion in adduction and abduction, 30 degrees flexion, and 10 degrees hyperextension. The function of the wrist was perfect, and its strength was good. There was no pain. (Figs. 128, 129 and 130.)

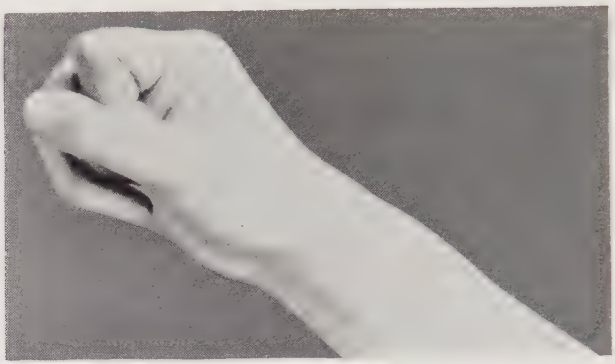

Fig. 130.—Case XXIV. A. H. End-result sixteen years after arthroplasty. Making a fist. (MacAusland.)

Résumé of Literature.—The number of arthroplasties of the wrist has been small, and one cannot fully judge the value of the procedure from the few cases that have been reported. Several successful results have been obtained, and undoubtedly as the technique of operation comes to be perfected, and the cases are selected more carefully for arthroplasty, there will be an increase in the percentage of good results.

Lexer[1] has reported a larger number of wrist arthroplasties than any other surgeon and he has had remarkable success. In a series of 14 cases he did not have a single failure. Lexer terms a result successful when the mobility is normal, or at least sufficient for daily use. To expose the joint Lexer uses a curved dorsal incision. The tendons are removed from their sheaths and retracted. In the formation of the joint-ends, he molds from the fused carpal bones a joint head, broad toward the front and cut off behind and at the sides. On the radial end a crescent-shaped cavity is formed, into which the new joint head will fit. Free fatty tissue is used for the interposed material. If the ulna is fused to the radius, a flap of fatty tissue is

interposed also between these two bones. If operations are necessary to free the tendons from cicatrized masses, or if substitution of the tendons is required because of vast destroyed areas, Lexer recommends that these accessory measures should be carried out a few weeks before or after the arthroplasty.

Kanavel[2] has had some experience in mobilizing ankylosed wrist-joints. Some of his cases had had previous inflammation of the tendons. If this involvement was only slight, Kanavel found it possible to restore complete function by a mobilizing process. His method includes the removal of both the proximal and distal row of the carpal bones and the excision of all intervening tissue. If possible, the bones are removed through a lateral dorsal incision only. Pedicled flaps of tissue are inserted in the cavity thus prepared. If it is not possible to secure material from the vicinity of the joint, pads of fat may be taken from the abdomen or from the leg. The hand is fixed in the "cock-up" position with the fingers in semiflexion.

When the ankylosis is complicated by contractures and adhesions of the tendon sheaths, several operations may be necessary before the patient obtains relief. The mobilizing process is done first by the method described above. Then the tendons are freed from the scar tissue, or if necessary, they are repaired by cicatricial bands. If there is no connective tissue present that may be used for tendons, strands of silk, a free transplant of fascia, or other tendons can be inserted. The tendons are covered with layers of fat. Such technique requires scrupulous care.

Comment: Kanavel's method involves the removal of such a large amount of bone that, in the opinion of the writers, the operation is an excision of the wrist or carpus rather than a true arthroplasty.

Nélaton[3] seems to have been the first to report an arthroplasty of the wrist. In 1905, he issued the details of 2 cases. One case in which Ombredanne had performed an arthroplasty, resecting the bones and interposing a tendon flap, was a failure. The second case, in which Nélaton himself used an arthroplastic procedure resecting the bones and interposing a muscle flap from the common extensor, was successful. Complete flexion and extension of the wrist resulted.

Hoffa[4] reported 1 case. His technique consisted of resecting the

first row of carpal bones and inserting a flap of fat and fascia, which was taken from the proximal side of the wound. Eleven months after operation, there was excellent function in the wrist and fingers.

Stein[5] reported an arthroplasty which was performed by Bier in his clinic in 1907. After an arch-shaped resection of the bones, he interposed a muscle flap. Two years after operation, the passive motion was good, but the function was unsatisfactory, due to the cutting of the flexor tendons by the patient who was demented.

Durán[6] used Baer's membrane in 1 case. One month after operation, the patient had a painless mobility of about 50 per cent.

In Murphy's[7] work are mentioned 3 arthroplasties of the wrist-joint. In one case, of infectious origin, the radius and scaphoid were fused, but the semilunar was free. A flap of superficial fat and fascia was interposed. Limited motion of about 15 degrees was obtained by the operation. The second case was that of a woman who had suffered from a chronic, recurring, multiple arthritis of six years' duration. Both wrists were stiff. In the arthroplasty on one wrist, Murphy made a slightly curved longitudinal incision over the ulnar styloid process, dissected down on the ulna, and with an elevator separated the muscles, the tendons, the arteries, and the ligaments from the anterior and posterior surfaces of the wrist-joint. Care was taken not to dissect the periosteum from the bones. Sufficient bone was removed to make a space into which the flaps would fit. A pedicled ulnar flap of fascia and fat was taken from the outer anterior surface of the wrist. The flap was passed over the ends of the bones, and the tip was brought to the radial side of the joint, where it was fastened to the periosteum and to the fibrous tissue. A radial flap was interposed in like manner. The arm was dressed in slight anterior flexion, and held in the elevated position by means of a wire-gauge splint.

Five weeks later, Murphy performed an arthroplasty upon the other wrist, the carpal bones of which were completely fused to the ulna and the radius. A radial incision only was made. About $\frac{5}{8}$ to $\frac{3}{4}$ inch of bone was removed from the lower ends of the ulna and the radius. The division of the ankylosis was semicircular with the concavity lying upward. A flap from the dorsum of the radial side of the forearm was interposed between the two forearm bones and the carpus. The tip of the flap was brought through the joint and fastened to the joint capsule on the ulnar side.

The end-result is not reported. While the patient was still in the hospital, the conformation of the right wrist was almost normal. The left wrist had luxated slightly to the radial side.

More recently, Putti[8] reported a case in which the free-fascia method was used. Details of the case were not given in his report.

Further use of the fascia method was reported by Okinczyc,[9] Lenormant,[10] Valls and Ottolenghi.[11] Okinczyc described a case in which Lombard and Goinard performed an arthroplasty. The ankylosis was complete, the hand was atrophied, and vasomotor and trophic disturbances were present. A dorsal incision was made. The bone-ends were separated and a piece of fascia lata was inserted. Eight months after operation, the flexion and extension were almost normal, and pronation and supination were complete. The wrist had good force. Lenormant's case was one of complete ankylosis of the radio-carpal-joint. The muscles of the forearm were extremely atrophied. The fingers showed atrophic disturbances and had only limited motion. Before operation, therapeutic treatment was carried out to improve the movement of the fingers and the condition of the musculature. At the time of the arthroplasty, the wrist was ankylosed in 20 degrees flexion and was absolutely fixed. There was bony fusion of the scaphoid and the semilunar with the radius, but the interline between the ulna and the carpus and between the radius and the ulna was preserved. All the bones of the carpus were fused into a block. Three and a half months after operation, active extension passed several degrees beyond the horizontal, and flexion to 35 degrees was possible. The joint was stable. There was indication that the movement would increase.

Valls and Ottolenghi[11] reported a successful result of arthroplasty in a case of double wrist ankylosis. The joints were stiff in 30 degrees flexion, and there was total fixation between the radio-carpal-, the medio-carpal-, and the carpal-metacarpal-joints of the four fingers. Fascia lata was used for a flap. One month after operation, the wrist could be flexed to 60 degrees, and could be moved laterally to 10 degrees. There was no pain.

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ARTHROPLASTY OF THE FINGER-JOINTS.

Limitation of motion in the fingers is of frequent occurrence. In the majority of cases, this limited function is the result of involvement of the periarticular structures of the phalangeal- and metacarpo-phalangeal-joints, and it is only in an occasional case that true bony ankylosis of a joint is present. When synostosis does exist, the pathological changes are due either to trauma of the joint accompanied by dislocation or followed by infection, or to direct infection of the hand or an individual finger. The presence of pathological disturbance within the phalangeal-joints secondary to an acute infectious process in the hand is evidence of the tendency of such infections to spread along the bloodvessels and nerves. Usually when the lesion has been of sufficient severity or extent to destroy the cartilage of the joint, pathological changes are present in the periarticular structures, especially in the tendons, which may be surrounded by adhesions or even entirely destroyed. The problem of mobilizing a finger-joint is, therefore, two-fold in the majority of cases, in that not only must a new joint be created, but also plastic operations are necessary to repair the tendon defects.

The functional position for the finger is about 30 degrees flexion. It is seldom, however, that one sees a finger stiff in this position. Most surgeons are so intent upon eliminating the septic process that they make little attempt to restore motion to the joint by treating it in functional position. Usually in cases of infection of the finger, ankylosis takes place in the extended position. If the hand is involved, the phalangeal-joints become fixed in flexion, and the metacarpo-phalangeal-joints in hyperextension. The thumb lies close to the hand in a useless position. Patients consulting the surgeon for stiffness of the fingers practically always present the members in a position of deformity. A finger ankylosed in the straight position is awkward, and it materially lessens the function

of the hand. The same handicap exists whether the finger is absolutely rigid or allows a few degrees of motion.

Treatment. The first step in the treatment of a stiff finger is the restoration of motion by the use of conservative methods. Manipulations and splinting are done to bring the hand and fingers into functional position, to lessen the adhesions, and to stretch the tendons. The manipulations should always be gentle. In many of the milder types, function can be entirely restored by these procedures, and very often the severe types will be benefited. Correction of wrist-joint deformity will always improve the function of the fingers.

In cases in which it is impossible to correct deformity and restore motion by non-operative measures, mobilization is to be considered, provided, of course, that the origin of the infectious process and the circumstances of the patient are conducive to a favorable outcome. Arthroplasty may also be considered in individual fingers ankylosed in flexion, provided the periarticular structures are in good condition. (See General Indications and Contraindications, p. 49.)

Arthroplasty of the finger-joints presents a complicated problem, not only because of the smallness of the bones, but also because of the presence of periarticular damage, particularly in the tendons. The atrophy is usually extensive and the skin and subcutaneous tissues are very delicate. There is liable to be a certain amount of lateral instability after arthroplastic procedures, which, however, does not cause any great inconvenience in a finger-joint. If the tendons are present, an arthroplasty may be performed with the assurance of obtaining good motion. When the tendon structures have been damaged, the arthroplasty must be supplemented by plastic operative measures before a complete return of motion can be obtained. When the tendons are embedded in scar tissue, they may be freed, and flaps of fat interposed between the tendons and the bone, and between the tendons and the skin. Kanavel,[1] who has had the most experience in this field, recommends the use of living fat with pedicles if they can be secured; if not, free transplants may be used. Following the operation, the hand is splinted in the functional position, and physio-therapy is persistently carried out. In cases in which the tendon sheath has been the site of the infection, with the result that the tendon is destroyed entirely or in part, restoration may be made by several means. Defects may be repaired by the use of strands of silk or by rolled strips of fascia lata. In some cases, the silk is

attached to the proximal end of the damaged tendon, and then inserted into the bone and periosteum. When the tendons and tendon sheaths have been completely destroyed, restoration is more difficult. Kanavel recommends restoring only one tendon—the deep flexor if possible. He prefers to use a transplanted tendon for this purpose, but if necessary, braided strands of silk, woven through any remnants of the scar tissue that may be present, or strands of silk alone may be applied. The silk is attached to the end of the tendon in the hand and brought through the scar tissue which is dissected from the old bed of the tendon, and fastened to the proximal end of the distal phalanx. The finger is then placed in marked flexion, and the silk is surrounded with living fat flaps taken from an adjacent area if possible, or by a free transplant if a pedicled one is not available. Flaps of fascia or scar tissue taken from nearby are passed about the tendon at the base of the finger to establish the slings that hold the tendon against the finger. Free flaps may be used for this purpose if necessary.

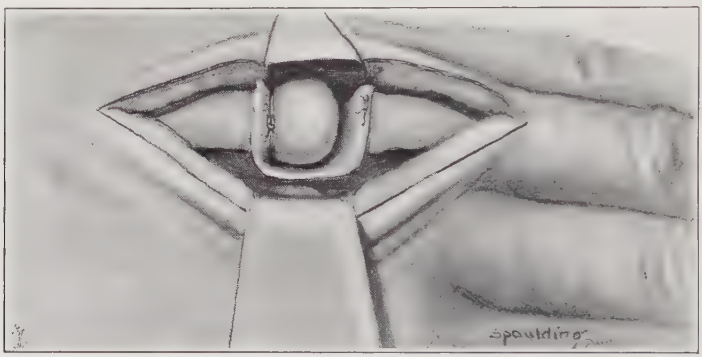

FIG. 131.—Finger arthroplasty. Insertion of double layer of fascia. (MacAusland.)

Operative Technique (Writers').—The entire hand to above the wrist-joint is prepared in the usual manner. At the time of operation a small tourniquet is applied. A longitudinal incision 3 inches in length is made on the dorsal surface just to the outer side of the tendon. When the skin and tendon are retracted, the capsule is exposed. A longitudinal incision is made in the capsule, and this tissue is separated from the distal and proximal phalangeal heads. The joint space is opened by means of a curved osteotome. A concave surface is modeled on the distal end of the phalanx, and a

convex surface is modeled on the proximal end of the opposing phalanx. The surfaces are very carefully smoothed with a file. A piece of fascia, which has been removed from the thigh, is attached to the proximal head, and a purse-string suture applied. (Fig. 131.) The capsule is closed insofar as possible, and the skin is closed with continuous catgut. The finger is placed in a palmar splint in about 20 degrees flexion. Gentle passive movements are started as soon as the sensitiveness and pain have subsided, usually in about ten days or two weeks. During the rest of the convalescent period, general therapeutic measures, such as baking, massage, and passive and active movements are carried out.

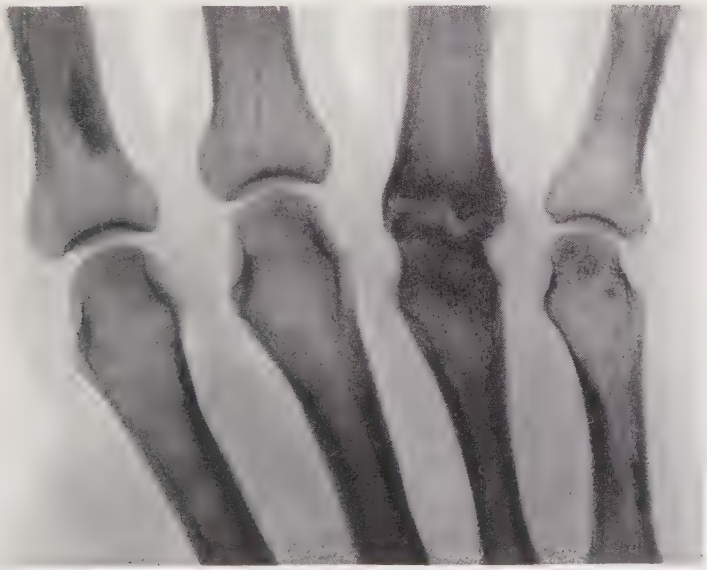

FIG. 132.—Case XXV. J. S. Roentgen film showing ankylosis of the metacarpo-phalangeal-joint of the third finger before arthroplasty. (MacAusland.)

CASE XXV.—J. S., aged thirty-seven years.

History.—September 12, 1926: While at work the patient struck the knuckle of the third finger of his right hand. Three days later, when he consulted a physician for treatment, the finger was swollen and discolored. A Roentgen film showed no fracture, disease, or dislocation. The finger was treated by hot fomentations and a bandage. Two weeks later the hand was badly swollen and extremely painful. A Roentgen film showed an osteomyelitis involving the joint and ends of the phalangeal and metacarpal bones. An operation was

done in which some necrosed bone was removed. The wound healed nicely, but the patient had a stiff finger. He was then referred to our clinic, and we advised him to return in one and a half years for arthroplasty.

Physical Examination.—May 3, 1928: There had been no discharge or swelling. The metacarpo-phalangeal-joint was very much thickened. There was only a spring in the joint, but motion could be easily increased to 15 degrees. There was pain when the joint was forced. A Roentgen film showed considerable destruction of the joint cartilage and some destruction of the shafts of the phalanx and the metacarpal. (Fig. 132.)

FIG. 133.—Case XXV. J. S. Roentgen film showing joint-space one month after arthroplasty. There is slight shortening from the removal of necrosed bone. (MacAusland.)

Treatment.—June 22, 1928: An arthroplasty was performed according to the method described above.

July 15, 1928: The finger had complete passive extension and 45 degrees motion in flexion. Hot fomentations and continual use of the fingers were advised.

July 28, 1928: There was flexion of 100 degrees and passive extension to 180 degrees. There was 20 degrees active flexion and the flexor power was good.

Result.—August 9, 1928: There was excellent muscle and tendon control. The joint was stable and had complete extension and 55

degrees flexion. There was still some thickening, and, of course, slight shortening from the removal of the necrosed bone. (Fig. 133.)

Case XXVI.—R. B., aged twenty-three years.

History.—This patient suffered a comminuted dislocation of the second joint of the second finger as the result of a baseball injury. The finger became stiff. Four manipulations to restore motion had been done, and a splint and plaster bandage had been worn, before the man entered our clinic.

Fig. 134.—Case XXVI. R. B. Roentgen film, showing ankylosis before arthroplasty. (MacAusland.)

Physical Examination.—A Roentgen film showed a fracture of the proximal joint of the second phalanx of the second finger, with comminution and dislocation. (Fig. 134.)

Treatment.—An arthroplasty was performed, *June, 1928.* When the sensitiveness disappeared, baking and massage were carried out daily. The fingers were kept on a splint.

July 17, 1928: There was about 35 degrees motion.

July 30, 1928: There was motion of 90 to 160 degrees extension. The joint was painless, but there was some swelling. Sun exposures were advised, and during one-half the day the finger was to be kept on a throat stick.

January 14, 1929: There is still some periarticular swelling, causing some soreness. The range of motion is now from 180 to 115 degrees.

FIG. 135.—Case XXVI. R. B. Roentgen film taken four months after arthroplasty. (MacAusland.)

Résumé of Literature.—Very few attempts have been made to mobilize the finger-joints. Kanavel[1] has done the most work in this field, and has secured satisfactory results from arthroplasty in several cases of ankylosis of the phalangeal-joints. His technique consists of the resection of the ankylosed joint, modeling of the articular ends, and the interposition of flaps of connective tissue, taken when possible from adjacent parts. Physio-therapy is an important adjunct.

CASE XXVII.—L. J. Courtesy of Dr. Kanavel.

History.—Due to an infection involving the tendon sheath of the right third finger, this patient lost the distal portions of the tendons of this finger and had a bony ankylosis of the proximal interphalangeal-joint in the position of flexion. (Fig. 136.)

Treatment.—The scar tissue was excised and the superficial tendon attached to the base of the proximal phalanx. The deep tendon was repaired with two strands of silk and attached to the distal portion of the middle phalanx. The distal end of the proximal phalanx was excised, the bone-end shaped, and flaps from the adjacent tissue (which were more or less unsatisfactory) were turned in between the proximal and middle phalanges. A free fat transplant was brought about the tendons and into the joint.

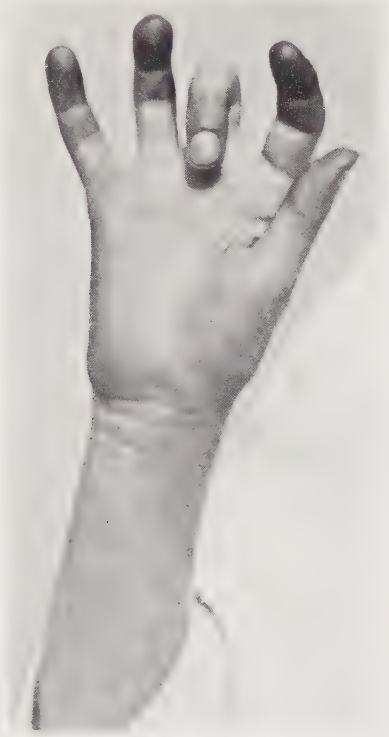

FIG. 136.—Case XXVII. L. J. Showing bony ankylosis of the proximal interphalangeal-joint of third finger, in position of flexion. (Courtesy of Dr. Kanavel.)

Result.—One year after operation the finger had complete function as to mobility at the proximal interphalangeal-joint, and the patient could flex the joint to a right angle. The patient could not move the distal joint. (Fig. 137.) It will be noted that the illustration of the finger in flexion shows a better condition than actually exists, because all the phalanges are in complete flexion. The patient has taught herself to grasp the distal phalanx with the ring-finger and bring it into flexion. This is now done automatically in making a fist.

Hofmann,[2] in a case of fibrous ankylosis of two interphalangeal-joints of the same hand, interposed periosteal transplants from the tibia. Six weeks after operation, there was good passive movement, but no active mobility.

Röpke[3] mobilized one case of finger ankylosis, using a free fat transplant. The case was successful.

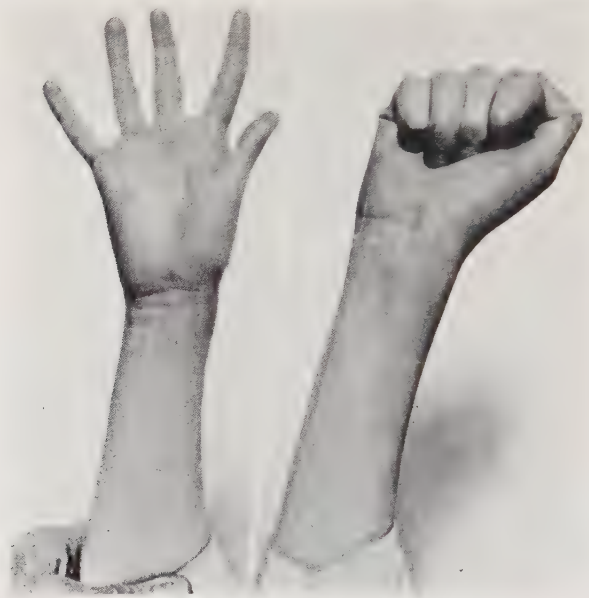

Fig. 137.—Case XXVII. L. S. Showing flexion and extension one year after arthroplasty. (Courtesy of Dr. Kanavel.)

Payr[4] reported 2 operations on the finger-joints, 1 for bony ankylosis of the first interphalangeal-joint of the middle finger, and 1 for ankylosis of the thumb. In the first case he used flaps of fat for interposition, and in the second case, a piece of the capsule. Painless joints with good motion resulted.

Gallagher[5] reported the result of an arthroplasty for traumatic bony ankylosis of the proximal interphalangeal-joint of the fourth finger. He did not describe his method. Two months after operation, the patient had voluntary flexion to about 45 degrees and extension to about 170 degrees, and he could carry 7.75 pounds on the joint.

Hamilton[6] reported success in arthroplasties on the phalangeal-

and metacarpo-phalangeal-joints. The incision for all phalangeal-joints was made parallel to the long axis of the finger. A mid-lateral incision was made on either side down to the capsular ligament. For the metacarpo-phalangeal-joints, an incision was made at the junction of the posterior and lateral surface on either side. The bones were mobilized by sawing two nicks about $\frac{1}{16}$ inch apart. The sawing was first done on the palmar surface and was not carried through the compact bone on the dorsal surface. Then the dorsal side was sawed through midway between the two nicks on the palmar surface. The piece of bone thus cut out contained the remains of the joint. The two lips of bone left on the dorsal surface were rounded and smoothed off, and left to prevent hyper-extension. All fragments of the capsular ligament were removed to avoid the setting-up of infection after operation. For interposition Hamilton recommended autogenous free flaps of fat and fascia. Extension was secured by means of a splint and adhesive plaster. Passive motion was instituted after two or three weeks. Hamilton cited a case in which such an arthroplasty was done for bony ankylosis of the thumb-joint and of the proximal phalangeal-joint of the index finger of the right hand, following virulent polyarthritis. The thumb-joint was mobilized first and the finger six weeks later. Within six months after the second operation, the patient was accepted as a naval recruit by the United States Navy.

In 1920, Schupatschoff[7] issued a review of the statistics of two groups of operations on fingers in the Russian army after the World War. The technique in general consisted of the removal of all dead tissue, the modeling of the proximal joint-ends to fit the distal ends, and the interposition of free transplanted autoplastic material. In some cases, fascia was used, in others part of the capsule, and in still others fat. In the first group of 67 operations following gunshot wounds, the amount of movement was best in the cases in which fascia was interposed. In the second group of 23 mobilizations for ankylosis following fractures, the results were not so favorable as in the first group, but again, the cases in which fascia was used were the most successful.

Lexer[8] reported a case of arthroplasty on the middle joint of a finger stiff in extension. A slightly curved incision was made on the ulnar side of the joint, the tendinous insertion of the long extensor was drawn aside, the bony growth on the head of the finger-joint was

removed, and a thin flap of subcutaneous fatty tissue was interposed. The patient, a violinist, was able to use his finger in playing.

Hesse[9] reported 14 cases of finger-joint mobilization, in 2 of which he interposed a layer of periosteum taken from the tibia, and in 12 free fascia lata. Of the first group, 1 patient secured complete use of the finger, and 1 had active mobility of 120 degrees and normal extension three and a half months after arthroplasty. Ten patients of the second group secured satisfactory mobility. In one case, the fascia sloughed, and there was no improvement. In another case, there was active motion of 100 degrees in the basal joint, but there was no movement in the middle joint, and the joint was unstable. Shortening amounted to 2 cm. In 4 cases it was necessary to remove the fascia.

Kofmann[10] mobilized a case of traumatic ankylosis of the right thumb in the carpo-metacarpal-joint. He resected the proximal end of the metacarpal-joint and interposed a double flap of fascia lata. In ten days the patient was using his thumb.

Brocq[11] mobilized a case of ankylosis of the second joint of the second finger. Following an economical resection and modeling, a layer of fascia lata was interposed. The case was not successful, re-ankylosis taking place in extension.

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ARTHROPLASTY OF THE METATARSO-PHALANGEAL-JOINT OF THE GREAT TOE.

The use of arthroplastic measures in the phalangeal-joints of the toes is limited to the metatarso-phalangeal-joint of the great toe, for the other articulations rarely become stiff, and if in an occasional case ankylosis does occur, it causes little inconvenience. Very often

it is not a bony ankylosis, such as we have been dealing with in the other joints, that causes a limitation of motion in the great toe; rather, the presence of an exostosis accompanied by a *hallux valgus deformity,* or by a *hallux rigidus* is the source of the restricted movement. In the advanced stages of these two pathological conditions, when the function is limited by the derangement of the mechanics of the joint, operative intervention is advisable. While many different surgical methods have been devised and recommended, we have found arthroplasty, consisting of the removal of a small portion of bone from the distal head of the metatarsal bone and covering this end with a bursal flap, the most satisfactory method. The aim of arthroplasty in such cases is not only to restore the movement of the joint, but also to correct deformity, which is unsightly and interferes with the fitting of shoes.

The general pathology of hallux rigidus and hallux valgus is much alike, and there are several etiological factors common to both conditions. Hallux rigidus occurs most commonly in young adults, particularly in men, whereas hallux valgus becomes increasingly frequent from adolescence to older life, and is much more common in women. The difference in the style of footwear undoubtedly explains the frequency of hallux valgus in women. The type of treatment for both conditions depends entirely upon the stage at which the joint is treated. Conservative treatment will relieve mild cases. In this treatise we are concerned with only the more severe and long-standing cases in which operative interference is required.

Hallux Valgus.—Hallux valgus is a deformity of the metatarso-phalangeal-joint of the great toe. The toe is abducted and rotated upon its own axis. The metatarsal shaft is abducted, and the phalangeals are adducted, leaving an abnormal space between the heads of the first and second metatarsal bones. In severe cases the great toe may lie under the other toes, or it may be so compressed that the forefoot takes on a conical shape.

Hallux valgus occurs most commonly from shoe defects. Shoes that are short, or high-heeled, or that do not have a straight inner line predispose the deformity. When a shoe is short and too pointed, there are two mechanical factors that lead to the development of a hallux valgus: (1) The shoe exerts both a lateral and longitudinal pressure, pushing the great toe-joint to the outer side of the foot; (2) the soft part of the shoe at the head of the metatarsal-joint

allows the foot to spread at this point. Short stockings have the same effect as short shoes in cramping the toes. Other etiological factors are: Lesions, such as periostitis or chronic arthritis, which cause changes in the shape of the head of the metatarsal bone; a disturbance of the muscle balance of the foot from inherent weakness of the muscle fibers as the result of disease, or from the general weakness common in pronated or weak feet; trauma; and flattening of the anterior arch.

The first pathological change that takes place is the formation of new bone on the outer side of the great toe-joint. Gradually, the distal head flattens from the increased pressure. As the overgrowth of bone increases it acts as a wedge to throw the joint into abduction. Compensatory changes take place in the proximal end of the first phalanx and lipping occurs. The cartilage on the exposed condyle atrophies. The sesamoid bones are displaced outward. The tissues on the outer side of the joint are lengthened, and those on the inner side are shortened. The continual irritation of the enlarged joint leads to the formation of a bursa, and hence, in most cases of hallux valgus there is redness over the great toe-joint, and in severe cases there may be a bursitis. The bursa sometimes becomes septic and occasionally the joint itself may be involved. With this bone and tissue pathology there is always flattening of the anterior arch; there is usually moderate contraction of the toes; and it is very common to find a mild exostosis on the outer side of the little toe from undue pressure against the shoe. In very severe cases there may be an accompanying periostitis around the edge of the capsule, or a traumatic arthritis in the joint.

The chief complaint, when the hallux valgus has developed to the stage of exostosis and bursitis over the joint, is deformity. A patient has a great deal of difficulty with each new pair of shoes until they become stretched and softened over the great toe-joint. There is always some limitation of movement, particularly in plantar flexion, and often in dorsiflexion, while the power of adduction, both active and passive, may be lost entirely. General symptoms include tenderness and pain due to the bursa, pronation and muscle weakness, and callous formations under the metatarsal heads secondary to the flattening of the anterior arches. Pain is further increased by the presence of a periostitis, or a traumatic arthritis, or from the pressure of the bony protuberances on the digital nerves. In severe

cases operative interference affords the only means of correcting deformity, of improving statics, and of restoring painless motion.

There are many operative procedures that have been used for hallux valgus. The general methods include: Resection of the metatarsal head with the removal of the exostosis; resection of the proximal end of the first phalanx and the removal of the exostoses on the metatarsal head; simple excision of the exostoses of the metatarsal bone; wedge-shaped osteotomy of the metatarsal or proximal phalanx to correct the deformity by a realignment of these bones; and finally a plastic operation in which the exostoses on the head of the metatarsal bone are excised, the lateral ligaments of the capsule and the adductor muscles divided, and a flap inserted between the phalanx and the metatarsal head. In general, these procedures have not proved satisfactory for several reasons: The technique is based upon principles of palliation rather than of cure; the methods do not aim to overcorrect the deformity and maintain the position of overcorrection after operation; the technique does not provide for the removal of sufficient bone, or the modeling of the metatarsal head, or the excision of painful sesamoids under the head of the metatarsal bone; and the procedures do not consider the general static deformity of the foot.

Credit for the development of an arthroplastic procedure for hallux valgus belongs to Mayo,[1] who originated the method of interposing a bursal flap. Excellent results have been obtained by the use of this procedure.

The arthroplastic method practised by the writers also gives excellent results. It secures correction of the deformity, provides for the restoration of motion in the joint, and preserves the weight-bearing portion of the head of the metatarsal bone.

Hallux Rigidus.—Hallux rigidus is a painful affection of the metatarso-phalangeal-joint of the great toe, characterized in the late stages by the production of considerable new bone, largely on the upper surface of the metatarsal head. The condition is often bilateral, but unilateral cases may occur from trauma of one joint. As a result of this arthritic condition and the development of deformity, the movements of the joint, particularly dorsiflexion, are either partially or completely limited, and painful callosities develop on the plantar surface of the distal phalanx from excessive pressure.

By far the most frequent cause of hallux rigidus is ill-fitting shoes. A narrow shoe that exerts pressure on the side of the foot, a short shoe which presses against the ends of the toes, or particularly one with a seam in the vamp that irritates the joint by pressure, may lead to the development of hallux rigidus. Other causes are the occurrence of slight injuries to the joint during the process of growth, and unusual strains, either occupational or traumatic. Sometimes hallux rigidus is a complication of a weak or flat-foot. Stubbing the toe or tripping, or injury from a heavy weight falling on the foot may give rise to unilateral pathology.

Pathological changes appear first in the tissues. The synovial membrane of the joint thickens and the cartilage degenerates. There is swelling and redness over the anterior surface of the joint. With the continuance of the irritation, a true bursa forms. The cartilage around the sesamoid bone on the plantar surface of the joint becomes inflamed, a pathological change that is a potent factor in rigidity. In the later stages bone changes occur. The head of the metatarsal bone flattens, and a ridge of bone surrounds the margin of the joint surface. Associated changes in the form of lipping take place in the proximal end of the first phalanx. The mechanics of the joint are seriously disturbed when these bone changes take place. Painful callous formations develop under the distal phalangeal-joint, which bears the brunt of the weight in walking when dorsiflexion of the great toe is restricted.

In cases in which there is complete loss of dorsiflexion and derangement of the mechanics of the joint by enlargement of the bone, operative treatment is necessary. The surgical procedure must be directed at the joint, for simple methods, such as the removal of bony spurs, rarely afford relief. The writers have consistently secured good results by the use of arthroplasty, the method used in hallux valgus.

Operative Technique (Writers').—A two-day preparation is given to the operative field. At the time of operation a tourniquet is applied.

A curved incision is made, beginning on the lateral aspect of the first phalanx, and running parallel to its shaft until it reaches the region of the joint; then it curves toward the plantar surface of the joint, and terminates on the lateral aspect of the first metatarsal bone. (Fig. 138.) The flap is dissected and retracted with double hooks.

FIG. 138.—Line of incision. (MacAusland.)

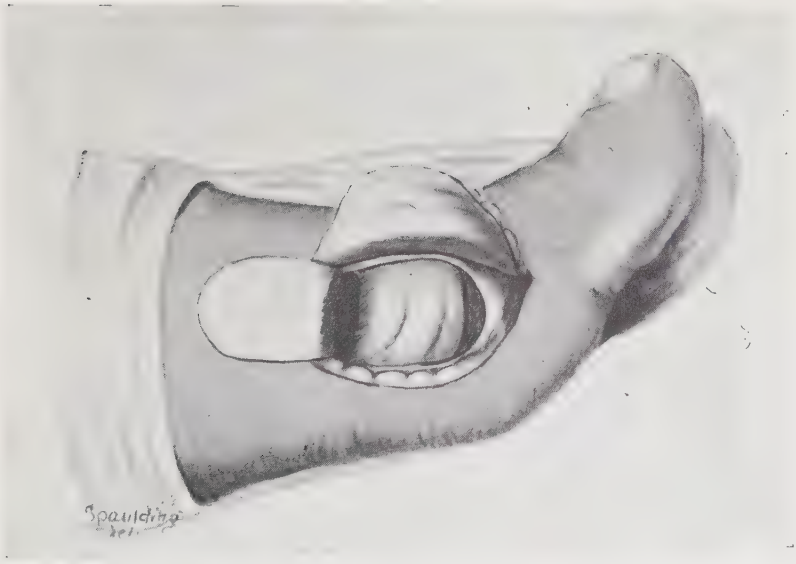

FIG. 139.—Exposure of joint. (MacAusland.)

A curved incision is then made through all the remaining tissue, including the bursa, the capsule, and the fascia. The incision begins under the head of the first metatarsal on the lateral plantar surface, sweeps about $\frac{1}{4}$ inch over the base of the first phalanx, and ends at a point on the lateral dorsal aspect of the first metatarsal, opposite the point of origin. The flap is dissected back and the joint exposed. (Fig. 139.) About $\frac{5}{8}$ inch of bone is removed from the head of the first metatarsal, and the edges are smoothed with a file or shoe-

FIG. 140.—Excision of small amount of bone from metatarsal head. (MacAusland.)

maker's rasp. (Figs. 140, 141 and 142.) This step is very important. The fascial flap is then brought into the joint-space by passing two chromic sutures first through the free end of the flap, one at each end, then passing the sutures through the plantar surface of the great toe-joint, and tying them outside on the plantar surface. Thus the flap is pulled well into place. (Fig. 143.) Another means of holding the fascia in place is to suture it to the capsule at the bottom of the joint, which has been undisturbed, but it is often

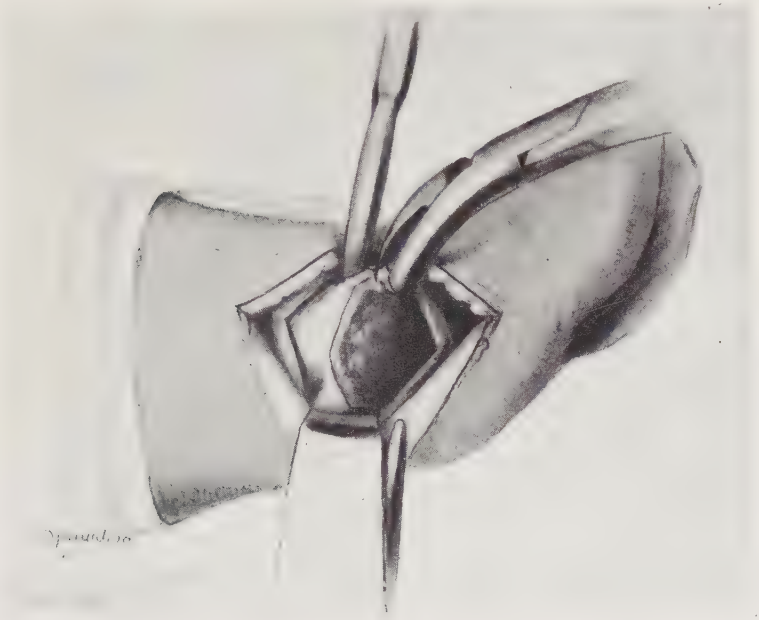

FIG. 141.—Rounding distal end of metatarsal head. (MacAusland.)

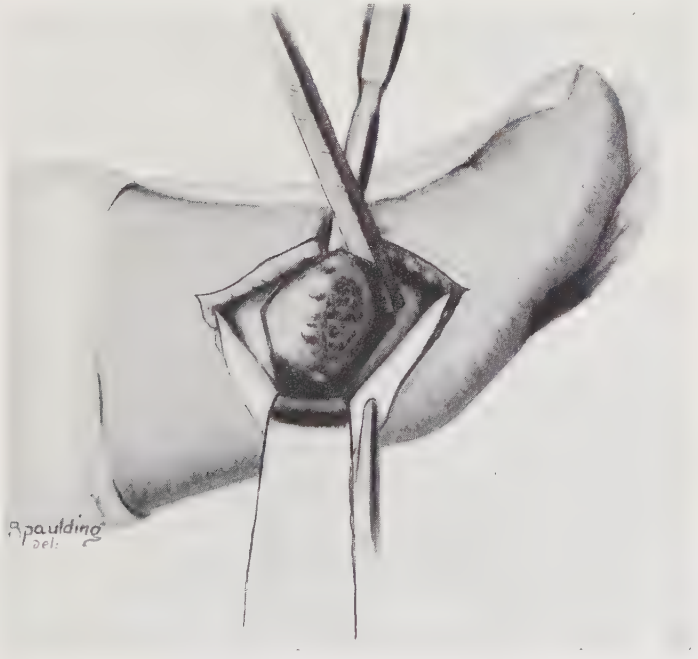

FIG. 142.—Smoothing and filing metatarsal head. (MacAusland.)

difficult to pass a needle into the bottom of the cavity to secure sufficient tissue to hold the flap firmly in place. The skin is closed with continuous catgut and a dry dressing applied. The toe is bandaged in the position of varus and slight plantar flexion.

After-treatment.—The toe is maintained in the position of over-correction for ten days. There is always a certain amount of swelling, which may be controlled by bandaging until the time when an anterior-arch support may be used. Most cases require an

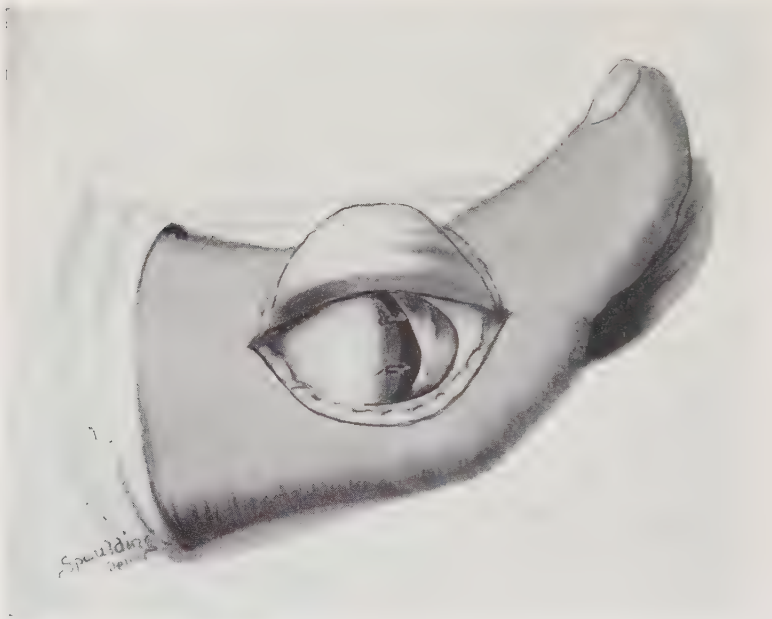

FIG. 143.—Flap sewed in place. (MacAusland.)

anterior-arch strapping and support for about two or three weeks, as the change in the weight-bearing line of the great toe-joint produces a mild periarthritis in the metatarsal heads of the smaller joints. When the sensitiveness has subsided, usually in two or three weeks, baking, massage, hydrotherapy, and gentle passive exercises are begun. The increase in motion is regulated according to the pain and degree of swelling. Some form of anterior-arch support must be worn for a few months following operation.

FIG. 144.—Case XXVIII. B. C. Showing plantar flexion of toe, one year, five months after arthroplasty. (MacAusland.)

FIG. 145.—Case XXVIII. B. C. Showing dorsiflexion of toe, one year, five months after arthroplasty. (MacAusland.)

Cases.

Case XXVIII.—B. C., aged forty years.

History.—The patient had suffered pain in the right great toe for years. It came on gradually and was arthritic in origin. The toe finally became stiff.

Fig. 146.—Case XXIX. D. R. Antero-posterior Roentgen film one year, eight months after arthroplasty. (MacAusland.)

Physical Examination.—There was an exostosis on the right great toe-joint. Dorsiflexion was limited to 180 degrees. The patient stood with both feet pronated. A diagnosis of hallux rigidus was made.

Treatment.—July 13, 1922: A regular arthroplasty was performed.
Result.—December 7, 1923: Excellent function in dorsiflexion and plantar flexion was obtained. (Figs. 144 and 145.)

FIG. 147

FIG. 148

FIGS. 147 and 148.—Case XXIX. D. R. Showing plantar and dorsiflexion of right great toe, one year, nine months after arthroplasty. (MacAusland.)

Case XXIX.—D. R., aged forty-five years.

History.—For years this patient had complained of increasing pain and stiffening in the great toe-joints. More recently she was disabled because of loss of motion and enlargement of the joints.

Fig. 149

Fig. 150

Figs. 149 and 150.—Case XXIX. D. R. Showing plantar and dorsiflexion of left great toe, one year, nine months after arthroplasty. (MacAusland.)

Physical Examination.—There was a marked exostosis on the top and on the outer side of both joints. Motion was limited. A diagnosis of hallux valgus was made.

Treatment.—February, 1921: Arthroplasties were performed on both great toe-joints.

April 8, 1921: There was good motion in the joints. Anterior-arch padding was being worn. The subsequent convalescence was without pain or swelling.

Result.—November 17, 1922: The motion was perfect. (Figs. 146, 147, 148, 149 and 150.)

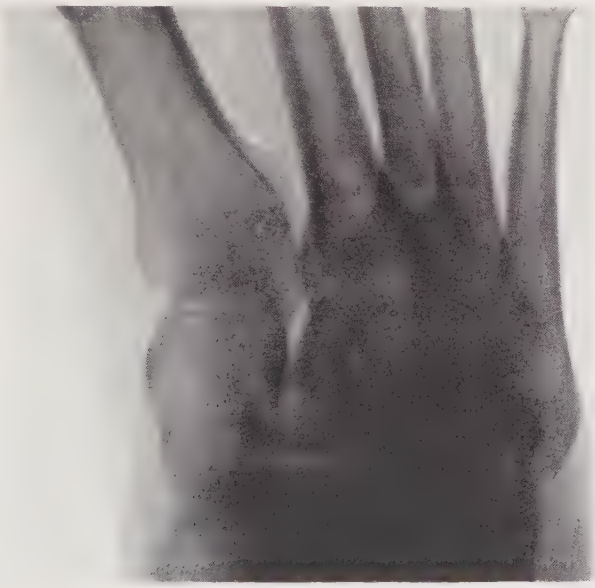

FIG. 151.—Case XXX. H. K. Roentgen film showing well-rounded head of first metatarsal with proper amount of joint surface preserved. (MacAusland.)

CASE XXX.—H. K., aged thirty-five years.

History.—The great toe-joints had been enlarged since childhood, a condition caused probably by wearing short shoes. There had been pain in the joints, particularly in the right, for a year.

Physical Examination.—There was a moderate hallux valgus on the left foot, and the anterior arch was a little low. All motions were free and unlimited. On the right foot the great toe-joint was distinctly limited in plantar flexion and somewhat limited in dorsiflexion. There was marked exostosis around the right great toe-joint. The anterior arch was flat.

Treatment.—Strappings were applied several times, but without securing relief.

May 13, 1921: An arthroplasty was performed on both great toe-joints.

Result.—October, 1928: Seven years after arthroplasty there was excellent motion in plantar flexion and dorsiflexion. (Figs. 151, 152 and 153.)

FIG. 152

FIG. 153

FIGS. 152 and 153.—Case XXX. H. K. Showing plantar and dorsiflexion of left great toe, seven years after arthroplasty. (MacAusland.)

Résumé of Literature.—Very little has been published on the statistics of the results of arthroplastic measures in the great toe-joint. Undoubtedly, procedures of this nature, which give excellent results in the toe-joint, are used more frequently than one is led to believe from the published reports.

The use of arthroplastic measures for deformities of the great toe evolved from Hueter's[2] suggestion, which consisted of a subperiosteal resection of the head of the metatarsal bone. The procedure did not prove satisfactory, mainly because the straight surface of the metatarsal bone and the concave surface of the

proximal end of the first phalanx did not fit together. Hence, stiffening of the joint and limited mobility resulted. This procedure, however, furnished the basis for other procedures. Modifications were made by Hamilton,[3] who suggested using a curved incision to keep the scar away from a possible pressure area, and by Mayo who proposed the interposition of a bursal flap, thus converting the operation into an arthroplastic measure.

The Mayo operation has come to be used more extensively than any other procedure. It consists of the removal of $\frac{1}{4}$ inch of the articulating surface of the head of the metatarsal bone, thus relaxing the extensor and flexor tendons. The bony overgrowth on the inner side of the head is removed, and the bunion bursa turned into the joint. If the hallux valgus is extreme the tendon of the extensor hallucis longus is split for $\frac{1}{2}$ inch over the joint and sectioned at the top on the inner side and at the bottom on the outer side. The tendon is allowed to slip $\frac{1}{4}$ inch and is sutured. The operation is most successful except in cases of marked flat-foot in which a fallen arch is complicated by a mild arthritis. In such cases the head of the bone and the bunion bursa are preserved, and the overgrowth of bone and the sesamoid bones are removed.

Keller[4] made other suggestions in advocating the removal of part of the proximal head of the first phalanx, excision of the exostosis by a cut obliquely upward, and wrapping the soft parts over the extremity of the phalanx. Keller believed that this procedure had the advantage of retaining the original weight-bearing surface and of shortening the convalescence. The operation, however, has not become popular because it is not based on the correct principle of remodeling the joint surfaces.

Murphy[5] used his fat-fascia method in a case of ankylosis of the phalangeal and metatarso-phalangeal-joints and secured good motion. Murphy made an incision on the dorsum of the toe and inserted a pedicled flap of fat and fascia taken from the inner side of the foot. Later Murphy outlined his operative technique for hallux rigidus as follows: A curved incision with its convexity outward is made along the extensor tendon. The tendon is incised and elongated. The metatarsal head is resected, and the bursal capsule is interposed for a flap.

Putti[6] reported one arthroplasty for an ankylosis of the metatarso-phalangeal-joint of the great toe. He made a longitudinal incision

on the inner side of the joint, removed two large sesamoids that contributed to the stiffness, excised all the capsule, and interposed a flap of fascia lata, wrapping it about both joint surfaces. He also shortened the extensor tendon. A plaster bandage was applied to hold the toe in a dorsal position.

Lexer[7] reported 3 successful cases in which he used flaps of fat. Silver[8] devised an operation requiring very skilful technique, in which the joint capsule was used for a flap. This procedure has only a limited application.

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PART IV.

THE PREVENTION OR MINIMIZATION OF ANKYLOSIS.

The possibility of preventing, or of minimizing the extent of the ankylosis in which certain joint lesions invariably result, depends upon the nature of the pathological process in the joint. *Tuberculous* joint lesions practically always terminate in ankylosis, and this result is to be desired. In truth, ankylosis, provided it is of the osseous variety, is probably the safest and most satisfactory outcome of the disease. When *osteomyelitic* infection extends into the joint ankylosis usually results, but motion may be retained in a few cases by early intervention. Unfortunately the majority of these cases do not receive proper surgical treatment at the stage when interference would be of value. An *acute septic* process in a joint usually results in ankylosis, but it is possible by early treatment to prevent union in some cases, and in all cases to minimize the extent of the synostosis. In many cases of *chronic infectious arthritis* motion may be preserved by careful treatment. *Traumatic lesions* offer the most favorable prognosis as to the return of motion. Provided a fracture is reduced shortly after injury, the return of motion is most promising. Other joint injuries, such as laceration of the ligaments, are followed by complete restoration of motion when conservative treatment is assiduously carried out.

THE RELATION OF THE RESTORATION OF MOTION TO THE TREATMENT OF JOINTS IN FUNCTIONAL POSITION.

The return of motion following any joint lesion is directly dependent upon the position in which the joint is maintained during convalescence. Regardless of the nature of the disease or trauma, the limb should be kept in proper functional position. (See Section on the Functional Position of Joints.) Not only is the return of motion more certain if the joint is maintained in its functional position, but also the period of convalescence is materially shortened. For instance, practically all lumbo-sacral or sacro-iliac lesions respond to treatment of the spine in hyperextension. An

acute back, due to injury or strain, is relieved by rest in bed, first on a fracture-board and later on a hyperextension roll, to keep the spine in normal functional position. The patient should be kept in bed until the straight leg-raising tests are normal.

The presence of deformity, on the other hand, actually favors the development of ankylosis. Not infrequently the limitation of motion following infectious lesions is due as much to treatment of the joint in malposition as to the septic process itself.

THE TREATMENT OF TRAUMATIC LESIONS.

If the traumatic lesion of a joint is properly treated the prognosis as to the return of complete function is favorable.

A fracture should be reduced immediately following the injury, and the joint placed in perfect anatomical position. Passive motions should be started early and regulated carefully according to pain. Forced motion in the presence of pain tends to cause an acute periarthritis and stiffness, which lead eventually to ankylosis. We have seen many elbow fractures which, following reduction, were demonstrated by Roentgen films to be in good anatomic reposition with only a few fibrous adhesions, but which finally resulted in ankylosis because repeated manipulations were done in the attempt to secure motion. It seems to be the customary practice to perform a manipulation as soon as motion shuts down. The result of this forced motion invariably is a decrease of function and a step favoring ankylosis. It is far more satisfactory to keep these joints quiet by means of bandages, slings, and apparatus, until all acute swelling, sensitiveness, and pain have subsided. When such manifestations have disappeared the patient may begin voluntary motion. The function is gradually increased, always under the supervision of the operator, so that the joint is never forced.

Following many types of traumatic lesions of joints, in which ligaments are torn, a definite periarthritis persists. The limitation of motion in these cases may be entirely out of proportion to the symptoms and appearance of the joint in Roentgen films. Such lesions are most often seen in the knee and the elbow. By keeping the circulation active and avoiding overexercise and manipulation, good motion can be restored. The following case shows the return of motion that is possible under conservative treatment.

Case XXXI.—W. P. *December 4, 1926:* The diagnosis of traumatic periosteal arthritis of the right elbow was made. The patient had previously suffered two injuries of the joint, one on October 25, 1926, during a football game, and the other, November 26, 1926, while vaulting a wall. Following the first injury the patient was unable to straighten the arm to within 35 degrees of normal, and flexion was limited. The arm could not be used because of pain. There was pain after the second injury, but no special trauma.

Physical Examination.—The condylar alignment was good. There was motion from 45 to 110 degrees. There was tenderness over the head of the radius. Rotations were normal. A Roentgen film showed little islands of bone in the region of the anterior external condyle, leading us to believe that the periosteum was torn at this point. (Fig. 154.)

Fig. 154.—Case XXXI. W. P. Roentgen film showing little islands of bone in region of the anterior external condyle, following a traumatic periosteal arthritis. (MacAusland.)

Treatment.—A flannel bandage and sling were applied.

December 29, 1926: There was no pain and no swelling. Motion from 30 degrees flexion to 155 degrees extension was possible. Supination and pronation were normal. Treatment was continued.

January 27, 1927: There had been a gain of 15 degrees in extension.

Result.—April 4, 1927: The patient had normal motion. There was no swelling or heat.

THE TREATMENT OF ACUTE SEPTIC JOINTS.

The infection giving rise to an acute septic process may penetrate into the joint in several different ways. A trauma that tears the tissues or introduces a foreign body into the joint may allow the pyogenic bacteria to enter. The infection may force its way into the joint from a septic focus in an adjacent part. Finally, the bacteria may be deposited in the joint by the blood, which carries the infection from some focus elsewhere in the body. The types of pathogenic organisms found most commonly in acute arthritic joints are the streptococcus, the staphylococcus, the gonococcus, and the pneumococcus.

As a rule, an acute septic process in a joint results in ankylosis. The only possibility of preventing fixation lies in thorough treatment during the early stage of the infection. Although there are few cases in which even early treatment will prevent stiffness, still, proper care during the incipient stages of the articular lesion will lessen the damage to the synovial membrane and help to prevent the formation of fibrous adhesions. Hence, the extent of the ankylosis will be minimized.

There are two methods that may be used in treating acute septic joints—the *Carrel-Dakin method* and the *Willems method*. Both procedures call for early radical opening of the joint, but the Carrel-Dakin method secures the elimination of infection by means of lavage, whereas the Willems method relies upon active movement to expel the pus. The wounds, except in the case of infection of gonorrheal origin, are left open until the joint is thoroughly clean. In gonorrheal infection the joint must be closed immediately after irrigation. The Carrel-Dakin method is used far more commonly today than the Willems method.

Carrel-Dakin Treatment.—The joint is opened up very thoroughly, the number and size of the incisions depending upon the joint being treated. All foreign material, all necrosed or lacerated tissue, and any skin, aponeurosis, or tissue that is likely to mortify are systematically resected. All blood-clots are removed, and careful hemostasis of the whole area is practised. The wound is cleansed. Dakin's solution modified with sodium bicarbonate is distributed to all parts of the joint by means of an arrangement of small elastic tubes connected with a single tube, which is attached to an irrigating

bottle. The disposal of the tubes varies with the position of the joint. The irrigation is kept up constantly or repeated every two hours. The joint is absolutely immobilized. Traction may be applied to prevent muscle spasm.

From the beginning of the treatment the guide for therapeusis is the bacteriological study of smears made from every part of the joint. When the discharge from the joint has remained sterile for two or three days, the wounds are allowed to close or are pulled together with sutures. Care is taken to preserve, insofar as possible, the capsular and ligamentous structures of the joint.

Willems' Method.—This procedure is based upon the principles of securing good drainage and establishing normal function. The joint is opened thoroughly by incisions. The bleeding vessels are tied. Neither irrigation nor drains are used. A loose dressing is applied. Upon the patient's recovering consciousness he is encouraged to move his joint voluntarily to bring about the expulsion of the pus. At first the discharge is a thick pus, then follows a fluid, and finally there are only a few drops of serum. The incision is kept open by passing a swab or forceps between the edges daily. The dressing is changed about twice a day. During the *convalescent stage* measures are carried out to restore motion. Baking, massage, diathermy, electricity, heliotherapy, hydrotherapy, and carefully regulated exercises are of benefit.

THE TREATMENT OF CHRONIC ARTHRITIC JOINTS.

A chronic arthritic process in a joint, when it is due to an infectious cause, is usually metastatic in origin. One of the first steps in treatment, therefore, is the elimination of all possible sources of infection. The teeth, tonsils, sinuses, genito-urinary tract, gastro-intestinal tract, or upper respiratory tract may be the site of the septic focus. In some instances it may be difficult, or even impossible, to determine the location of the primary infection.

If the chronic arthritis is the result of static disturbances, faulty posture, or overweight, in other words, if the joint changes are chiefly of a hypertrophic nature, the removal of the primary cause of the joint disturbance is essential. Very often the surgeon overlooks the elimination of these etiological factors and is content with relieving the local symptoms. Such lesions as flat-foot should be

corrected; inequality of balance should be compensated by the use of apparatus; paralytic deformities should be corrected or controlled; and excessive weight should be eliminated.

The local treatment of chronic arthritic joints is entirely dependent upon the stage of the process. During the *acute* or *subacute* stages the patient should rest in bed, with the limb maintained in proper functional position and carefully protected from strain. Movement may be permitted to the degree the patient desires. It will be noted that this treatment of chronic infectious joints is directly opposed to the popular procedure of exercising the joint to prevent stiffness. We have seen so many arthritic joints become ankylosed as the result of overexercise, that we are strongly opposed to the use of active motion and manipulations during the acute and subacute stages. At this time there are usually adhesions within the joint. Forced exercise or manipulations produce a breaking up of these adhesions, with the result that there is extravasation of fluid into both the periarticular structures and the joint proper. The joint becomes painful and sensitive and the next day it cannot be moved. The suffering of the patient is increased, and relief is not secured until re-ankylosis takes place. Certainly such treatment tends to lead to the development of ankylosis more readily than rest and protection of the joint.

In an occasional case of an acute flare-up of a chronic arthritis in a knee we are finding it of advantage to treat the joint by open intervention, as we would an acute septic joint. It is in the boggy, thickened joint filled with fluid that operative interference is of benefit. Usually such joints are flaky in appearance and occasionally rice bodies may be found, which should be removed. Thus far we have carried out this procedure only in the knee-joint. The results have been very satisfactory.

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